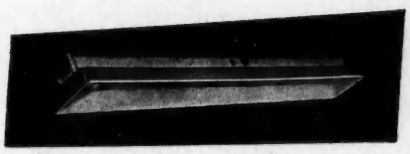
5 into one will go

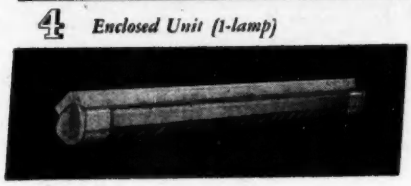


1 *Closed End Metal Trough*

2 *Open End Metal Trough*

3 *Closed End Translucent Trough*

4 *Enclosed Unit (1-lamp)*



5 *Louvre Unit (1-lamp)*

These METROVICK 5-foot fluorescent units all utilise a standard basic channel in which the instant start or switch gear is housed. They are suitable for chain, conduit or direct ceiling mounting. Erection of the ceiling mounting type is greatly simplified by the use of slotted backplates and horseshoe washers which support the unit during fixing. Turret lamp holders permit easy replacement of lamps from either end. METROVICK 5 ft. fluorescent fittings are constructed of sheet steel, bonderised and with a stove enamel finish.

METROVICK 5ft
fluorescent fittings

TROPOLITAN-VICKERS ELECTRICAL CO. LTD.
PAUL'S CORNER, ST. PAUL'S CHURCHYARD, LONDON, E.C.4
Member of the A.E.I. group of companies.

S/F407

THE ENGINEER

ESTABLISHED 1856

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PRINCIPAL CONTENTS

(Complete contents on page 850)

Scientists and Engineers 850

Combined Tension and Torsion Machine for Relaxation Tests 834
(A. E. JOHNSON AND N. E. FROST)

Clarification of Surface-Water Sewerage Theory—No. I 835
(L. B. ESCRITT

Calculation of Losses in Transformer Cores—No. I 837
(A. LANGLEY MORRIS)

Glass Fibre Plastics in the Chemical Industry—No. I 839
(F. F. JARAY)

Melting Shop with a 60-ton Electric Arc Furnace ... 843

Foundations for High Buildings 848
(A. W. SKEMPTON)

Ventilated Silos for Grain Drying and Storage ... 859

Motorways and High Buildings 850

NOTICE TO READERS
All letters intended for insertion in 'The Engineer' or containing questions should be accompanied by the name and address of the writer, not necessarily for publication, but as a proof of good faith. No notice whatever can be taken of anonymous communications. No undertaking can be given to return drawings or manuscripts; correspondents are therefore requested to keep copies.

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Advertisements received by Mid-day Tuesday will appear in the issue of Friday the same week. Orders must be accompanied by a remittance.

INDEX TO ADVERTISERS—PAGE 139

PUBLIC APPOINTMENTS

THE UNIVERSITY OF SHEFFIELD

CHAIR OF CIVIL ENGINEERING

Applications are invited for the newly established CHAIR OF CIVIL ENGINEERING, to be filled as soon as possible. Salary not less than £2000 a year, with F.S.S.U. provision and family allowance.—Further particulars should be obtained from the Registrar, The University, Sheffield, 10, to whom applications should be sent by 15th January, 1955. E6788

THE UNIVERSITY OF SHEFFIELD

CHAIR OF ELECTRICAL ENGINEERING

Applications are invited for the newly established CHAIR OF ELECTRICAL ENGINEERING, to be filled as soon as possible. Salary not less than £2000 a year, with F.S.S.U. provision and family allowance.—Further particulars should be obtained from the Registrar, The University, Sheffield, 10, to whom applications should be sent by 15th January, 1955. E6789

THE COLLEGE OF AERONAUTICS

DEPARTMENT OF AIRCRAFT ECONOMICS AND PRODUCTION

LECTURER

LECTURER required in the Department of Aircraft Economics and Production, to deal as far as possible with the following subjects : machine tools, aircraft production processes, jig and tool design, metrology, Candidates should be Graduates in Engineering or possess equivalent qualifications, and preference will be given to those with aircraft tooling experience. Salary within range £600 to £1000 p.a., with superannuation under F.S.S.U., and family allowance. Applications, giving full details of qualifications, &c., and quoting the names of three referees, should be addressed to the Recorder, The College of Aeronautics, Cranfield, Bletchley, Bucks. Further particulars available. E7089

INSTRUCTOR (MATHEMATICS AND MECHANICS)

MOMBASA INSTITUTE OF MUSLIM EDUCATION, KENYA

INSTRUCTOR (MATHEMATICS AND MECHANICS) required by the Mombasa Institute of Muslim Education, Kenya, for one tour of three years in the first instance. Salary scale (including present temporary allowance of 30 per cent. of salary), £715, rising to £1325 a year. Commencing salary according to experience. Free furnished quarters or an allowance in lieu. Outfit allowance £30, free passages, superannuation scheme, liberal leave on full salary. Candidates will be required to teach mathematics and mechanics to engineering students and should hold a B.Sc. (Eng.) Degree or be A.M.I.Mech.E.—Write to the Crown Agents, 4, Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience, and quote M2A/40434/EH. E7090

ESSEX EDUCATION COMMITTEE

SOUTH-WEST ESSEX TECHNICAL COLLEGE AND SCHOOL OF ART

FOREST ROAD, WALTHAMSTOW, E.17

PART-TIME DAY LECTURERS

Applications are invited for appointment as PART-TIME DAY LECTURERS, to teach up to Higher National Certificate standard, the following subjects :—

Engineering Materials.
Strength of Materials.
Theory and Design of Structures.
Engineering Geology and Soil Mechanics.

Forms of application may be obtained from the Clerk to the Governors. E7018

DESIGNING DRAUGHTSMAN, GRADE IIA (DRAWING-OFFICE)

EAST AFRICAN RAILWAYS & HARBOURS ADMINISTRATION

DESIGNING DRAUGHTSMAN, Grade IIA (Drawing-Office) required by the East African Railways and Harbours Administration for one tour of 40/48 months with prospect of permanency. Salary scale (including temporary allowance of 35 per cent. of salary) £958, rising to £1012 a year. Free quarters or an allowance in lieu. Outfit allowance £30. Free passages. Liberal leave on full salary. Candidates must have served a full apprenticeship with a British Railways Mechanical Department or a Locomotive Builder, followed by at least seven years' experience on design of locomotives and their components.—Write to the Crown Agents, 4, Millbank, London, S.W.1. State age, name in block letters, full qualifications, and experience, and quote M2C/30649/EH. E7026

LONDON COUNTY COUNCIL

MECHANICAL ENGINEERS AND TECHNICAL ASSISTANTS ALSO TRACERS

MECHANICAL ENGINEERS and TECHNICAL ASSISTANTS, also TRACERS, required for the preparation of plans, specifications and estimates, general mechanical engineering projects, experience in large heating and ventilation systems an advantage. Salaries according to qualifications and experience. Application form (returnable within 14 days) from Chief Engineer (54/70), London County Council, County Hall, S.E.1. (Enclose s.a.e.) (1589) E7017

PUBLIC APPOINTMENTS

STAFFORDSHIRE POTTERIES WATER BOARD

APPOINTMENT OF CIVIL ENGINEERING ASSISTANT

Applications are invited for the following appointment :—

CIVIL ENGINEERING ASSISTANT at a salary in accordance with the new Grade A.P.T. II (£560 to £640 p.a.).

Applicants must :—

(a) Have passed Part I of the Institution of Civil Engineers Examination and have at least two years' engineering experience ; or

(b) Hold a University Degree in Civil Engineering and have at least one year's engineering experience.

The appointment is subject to the provisions of the National Scheme of Conditions of Service ; to the provisions of the Local Government Superannuation Act, 1937 ; to termination by one month's notice on either side ; and to the successful candidate passing a medical examination.

Applications, stating age, full details of training, qualifications, present and previous appointments, details of experience, together with copies of two recent testimonials, or the names of two persons to whom reference can be made, should be forwarded to the undersigned not later than Tuesday, 28th December, 1954.

C. V. BROWN, M.I.C.E., M.I.Mech.E., M.I.W.E., Engineer and Manager and Clerk to the Board.
Staffordshire Potteries Water Board,
Albion Street, Hanley,
Stoke-on-Trent. E6987

NATIONAL COAL BOARD

CENTRAL RESEARCH ESTABLISHMENT

ENGINEER

Central Research Establishment, National Coal Board (at Isleworth, Middlesex), which is concerned with mining problems, invite applications for a superannuable appointment of an ENGINEER to lead a group carrying out research on coal cutting. The work is concerned initially with the problems of moving a cutting tool through coal at high speeds and associated power losses in machinery designed for this task.

Candidates should have a good Honours Degree in Mechanical Engineering or equivalent professional qualifications, proved research ability and preferably experience in the field of strength of materials.

Appointment will be as Scientist, Grade 1, and salary will be, according to qualifications and experience, within the scale £1150 by £40 to £1350, followed by a range to £1550 per annum (male), London location allowance of £82 at the minimum, rising to £100 at the maximum of the range being payable in addition.

Write, giving full particulars (in chronological order) of age, education, qualifications and experience (with dates), to National Coal Board, Establishments (Personnel), Hobart House, Grosvenor Place, London, S.W.1, marking envelope TT/891. Original testimonials should not be forwarded. Closing date 1st January, 1955. E7059

BOROUGH OF SHREWSBURY

WATER DEPARTMENT

APPOINTMENT OF AN ASSISTANT ENGINEER

Applications are invited from suitably qualified candidates with at least two years' practical experience in water supply for this post, the duties of which may include works in connection with the design and construction of aqueducts, service reservoirs, treatment works, &c., and normal maintenance. The salary, which will depend on qualifications and experience, will be within the new A.P.T. Grade III of the National scales (£600–£725 per annum).

Housing accommodation will be provided if required.

The appointment is permanent and is subject to the provisions of the Local Government Superannuation Acts, 1937–1953, and to a satisfactory medical examination.

Applications, stating age, qualifications and details of experience, together with the names of three persons to whom reference may be made, should be submitted to the Water Engineer and Manager, Water Department, Shelton, Shrewsbury, so as to be received not later than the 31st December, 1954.

S. R. H. LOXTON,
Town Clerk.

Guildhall,
Shrewsbury. E7019

CITY OF LEICESTER

WATER DEPARTMENT

ASSISTANT CIVIL ENGINEER

ASSISTANT CIVIL ENGINEER required by Water Department of the City of Leicester, to assist in designing and constructing works for water supply, including aqueducts, service reservoirs, and the development of a new source of supply. The appointment is a permanent one and the salary is within the range A.P.T. I–V (£490–£670 per annum), depending upon qualifications and length of experience.

Applicants should have passed Sections A and B of the Institution of Civil Engineers' Examination or should hold an exempting degree. Practical experience, particularly in water supply, is desirable, but not essential.

The appointment is subject to the provisions of the Local Government Superannuation Acts, 1937 to 1953, and to a satisfactory medical examination.

Applications, giving full details of training and experience, should be submitted to the undersigned before 6th January, 1955.

HAL WALLHOUSE, A.M.I.C.E., M.I.W.E., Engineer and Manager.
City of Leicester Water Department,
Bowling Green Street, Leicester. E6993

PUBLIC APPOINTMENTS

MECHANICAL ENGINEER

CENTRAL ELECTRICITY BOARD

MALAYA

MECHANICAL ENGINEER required by the above Board. Salary scale (including expatriation pay and present temporary allowance at rate for single men) equivalent to £1197, rising to £2100 a year. Commencing salary according to qualifications and experience. Additional temporary allowances totalling £210/£399 a year (married men) and £301/£630 (family men). Option of appointment either (a) on agreement for three years with prospect of permanency, or (b) on contract for three years with gratuity of £200 or £280 for each year's service, according to salary. Opportunity of terminating appointment after one year's service. Free passages. Liberal leave on full salary. Candidates must have served an apprenticeship with a firm of diesel engine manufacturers and have had not less than five years' experience on erection and/or maintenance of engines and power plant. They should have a knowledge of A.C. electrical generators of types normally driven by diesel prime movers. Preference will be given to candidates possessing a 1st Class M.O.T. Diesel Certificate. Write to the Crown Agents, 4, Millbank, London, S.W.1, State age, name in block letters, full qualifications and experience, and quote M2A/30065/EH. E7078

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

HYDRAULICS RESEARCH STATION

ASSISTANT EXPERIMENTAL OFFICERS

Department of Scientific and Industrial Research require ASSISTANT EXPERIMENTAL OFFICERS (unestablished) at the Hydraulic Research Station, Wallingford. Mechanical Engineer (Ref. C824/54A), for work on mechanical design of instruments. Workshop experience desirable. Electrical Engineer (Ref. D603/54A), for work on electrical design of instruments. Workshop experience desirable. Chemist (Ref. F851/54A), for work in Sedimentation Laboratory ; physics and chemistry are required subjects. Candidates should be at least 18 and have G.C.E. advanced level in Scientific and Maths. subjects or equivalent. Over age 22 a Pass Degree, H.N.C. or equivalent (in appropriate subjects) will generally be expected. Inclusive annual remuneration for a 45½-hour week in the range £284–£633 (men), £284–£530 (women). Favourable housing prospects for married candidates. Prospects of permanent establishment for candidates under 28.—Forms from M.L.N.S., Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting appropriate reference above. Closing date 15th January, 1955. E7025

MERSEY DOCKS AND HARBOUR BOARD

DRAUGHTSMEN

Applications are invited for :—

(a) A DRAUGHTSMAN, about 35 years of age or under. Experience in the design of dock machinery and appliances for steam and hydraulic power would be an advantage, also pipe installations and supporting steelwork.

(b) A DRAUGHTSMAN experienced in the general civil engineering work associated with a Dock and Harbour Authority, with a knowledge of general structural and building work, bridges, dock sheds, cranes and crane tracks, including reinforced concrete construction, &c.

Salaries will be in accordance with the Board's scale, on an efficiency and age basis. At the present time these salaries qualify for a cost-of-living bonus of 15 per cent.

Applications should be addressed to the Engineer-in-Chief, Mersey Docks and Harbour Board, Dock Office, Liverpool, 3, and received not later than the 1st January, 1955.

FRANCIS H. CAVE,
E6830 General Manager and Secretary.

MID-NORTHAMPTONSHIRE WATER BOARD

ENGINEERING ASSISTANTS

Applications are invited for posts of ENGINEERING ASSISTANTS on the Board's temporary staff for work in connection with the Board's construction programme, and for which there are two vacancies. Applicants should have some knowledge of reinforced concrete design or civil engineering as applied to waterworks.

Appointments will be made in the salary range £705 by £30 to £825, the commencing salary being in accordance with ability and experience.

Applications should be sent to the undersigned not later than 22nd December, 1954.

LEONARD H. BROWN,
Engineer and Manager.
Cliftonville, Northampton. E6918

BRITISH RAILWAYS

LONDON MIDLAND REGION

DESIGNER-DRAUGHTSMAN

DESIGNER-DRAUGHTSMAN with good knowledge of structural design and details in steel and reinforced concrete, experience in bridge work an advantage, able to take off quantities and prepare estimates. Commencing salary £660 per annum. Residential and certain other travelling concessions available.—Apply to Civil Engineer, London Midland Region, British Railways, Euston Grove, London, N.W.1. E7043

PUBLIC APPOINTMENTS

CIVIL SERVICE COMMISSIO

DEPARTMENT OF SCIENTIFIC A INDUSTRIAL RESEARCH

PRINCIPAL SCIENTIFIC OFFIC

The Civil Service Commissioners invite ap for a pensionable post at the Mechanical E Research Laboratory, East Kilbride, near G

The officer appointed will be required to team preparing tables of thermodynamic p Experimental data relating to functions variables are to be correlated.

Age at least 32 on 31st December, 1954. dates must have a First or Second Class Degree in Mathematics, Physics or Engin equivalent qualifications, and some post research experience. Exceptionally a without the prescribed qualifications may be A high degree of mathematical ability and a knowledge of numerical mathematics Experience in using calculating equipment sifting crude data an advantage.

Inclusive annual remuneration (for 45½-h £1122–£1516 (men), £1007–£1354 (women) tionally, a starting salary above the minim granted according to qualifications and exp

East Kilbride is a new town with good prospects.

Further particulars and application fo Civil Service Commission, Scientific Branch Burlington Street, London, W.1, quot S4402/55. Applications must be returned January, 1955.

FIFE COUNTY COUNC

COUNTY ENGINEER'S DEPART CUPAR

DRAINAGE ASSISTANT

Applications are invited for appoint DRAINAGE ASSISTANT in the above de Applicants should have good experien design of sewage disposal works. Co may be given to meeting housing requ Salary commensurate with experience and tions. The County Council have in han programme for the design and construction disposal works for isolated villages and for densely populated industrial areas. Further tion regarding the appointment and applica may be obtained from the County Engineer, Cupar-Fife. Applications should be lod the undersigned not later than 11th January

MATTHEW POU
County Clerk

County Buildings,
Cupar-Fife.

LANCASHIRE RIVER BOA

DIVISIONAL ENGINEER

Applications are invited from qualified for the appointment of DIVISIONAL EN Salary in accordance with new scale A.P.T. £1000 p.a.).

Applicants must have considerable exp the design and execution of land drainag The successful applicant will be required t and maintain a car for which an allowan paid in accordance with N.J.C. scales maximum of 10 H.P.

The post is superannuable.

Applications, stating age, marital statu tions, technical training and experience, p previous appointments with salaries, to the names and addresses of three persons reference may be made, should reach t Engineer of the Board at the undermentione not later than the 15th January, 1955.

H. HOLMES,
Clerk of the

48, West Cliff,
Preston.

THE PARSONS AND MA ENGINEERING TURBIN RESEARCH AND DEVELOP ASSOCIATION

RESEARCH ENGINEER

The Parsons and Marine Engineering Research and Development Association RESEARCH ENGINEER for work on vibration problems encountered in marine ing. Qualifications required are an Hono in Mechanical or Electrical Engineering with a recognised apprenticeship and a p ledge of applied mathematics. Applica of British nationality. Salary will be in with age and qualifications.—Apply in Research Director, Parsons Research Wallsend, Northumberland.

BORD NA MONA

MECHANICAL (DESIGN) EN

Applications are invited from experien ANICAL ENGINEERS for a vacancy work on experimental machines.

The vacancy exists at the Board's E Station at Newbridge, Co. Kildare. The applicant will be appointed in the scale £ £1173 15s.

A Mechanical Engineering Degree or qualification is essential. Candidates s experience of machine design. Experie cultural engineering and/or tracked ve earth-moving equipment would be advan

Applications, giving the fullest details tions and experience, to Secretary, Bord 28/31, Upper Pembroke Street, Dublin.

THE ENGINEER

DECEMBER 17, 1954

British Engineers' Association

ON Thursday of last week, the British Engineers' Association held its annual luncheon in London, the president, Mr. H. S. Broom, being in the chair. The principal guest was Mr. Gerhardt Jooste, High Commissioner for the Union of South Africa in the United Kingdom. In a short after-luncheon address Mr. Jooste recalled that through the years, in war and in peace, the United Kingdom and the Union of South Africa had always figured prominently among each other's best customers. It was equally significant, he said, that the trade of each country with the other had continued to grow in a manner which could only be described as phenomenal. Industrial development in South Africa, Mr. Jooste continued, did not begin on any substantial scale until after the first world war. The foundations were actually laid during the inter-war period and the most rapid expansion had occurred only since the last war. Industrial production in South Africa in 1939 was valued at £200 million, but since then, Mr. Jooste stated, it had risen to £1000 million and was still increasing. But it should be remembered, he added, that although South Africa's industrial development had covered a very large area of her economy, the majority of existing enterprises had been built to provide only a part of her requirements. The balance of what South Africa needed must still be imported. Mr. Jooste went on to mention machinery and electrical apparatus, commenting that United Kingdom exports in those categories to South Africa had reached a value of £48,000,000 in 1953. The easing of import controls in South Africa, he said, coupled with the maintenance and possible extension of such controls in other markets, might well make South Africa the United Kingdom's "best outlet" in 1955. It was encouraging to note, Mr. Jooste added, that, despite price cuts, export incentives, and the extended credits given by her main competitors, the United Kingdom had maintained her position in world markets, and in particular in the South African market. That, he considered, was a noteworthy achievement.

Examination Courses in Plant Engineering

THE council of the Incorporated Plant Engineers has approved a scheme for examinations in plant engineering which has been drawn up by the advisory committee of the City and Guilds of London Institute. The scheme, it is stated, is intended to meet the needs of those engaged in the selection, installation, maintenance or control of fixed or mobile plant throughout industry. The Incorporated Plant Engineers' council points out that the increasing mechanisation of modern projects, the heavy cost and often complicated nature of new plant and equipment, and the pressing demand for higher levels of production efficiency have added greatly to the responsibilities and to the importance of the plant engineering profession. The predominant aim of Incorporated Plant Engineers, therefore, is to promote the education and provide for the examination of students in the profession. The examination courses now approved meet the requirements for associate membership of Incorporated Plant Engineers and have been designed to follow the successful completion of an ordinary national certificate course in mechanical or electrical engineering. A certificate in plant engineering will be awarded to successful candidates, and the possession of the certificate will give exemption from the technical part of the entrance examination of Incorporated Plant Engineers. In addition, the City and Guilds of London Institute will award a full technological certificate to candidates who have gained the plant engineering certificate and have an ordinary national certificate or higher qualification. Full details of the examination scheme may be obtained from the City and Guilds of London Institute (Department of Technology), 31, Brechin Place, London, S.W.7, or from Mr. H. S. Seaborne, general secretary of Incorporated Plant Engineers, Solihull, Birmingham.

Lloyd's Rules for Modern Cargo Ships

INVESTIGATIONS into the structural damage and failure which have occurred, during recent winters, to several modern dry cargo ships resulted in the appointment in January of this year of a special Panel by Lloyd's Register of Shipping. This Panel has examined the results of the investigations and has recommended important amendments, to the Construction Rules, which it considers necessary to ensure a satisfactory standard of longitudinal strength for this class of ship. After due consideration by the Technical Committee, these amendments were adopted by the General Committee on December 9th and will be published and applied to new ship construction for which the plans are submitted for approval. The amendments are in two main parts. In the first formulæ have been devised and introduced into the rules whereby the minimum longitudinal scantlings, based on dimensions, will be increased as necessary to allow for modern design characteristics in respect of speed and distribution of cargo. This amendment has as its object the maintenance of the same standard of longitudinal strength for all classes of dry cargo ship and will apply irrespective of the method of hull construction. The second part of the amendments is concerned with welded construction and calls for the greatly extended use for the main hull of welded ships of specially approved notch-tough steels, of which a limited use was originally introduced into the rules in 1950. In addition, more specific requirements relating to detailed structural design have also been prescribed. The basic considerations governing the extended use of special quality steels in welded dry cargo ships also apply in general to oil tankers and the rules for this class of ship have been amended. The rules for the quality and testing of notch-tough steels suitable for welded construction are to be reviewed by a special Panel appointed by the Technical Committee of the Society.

B.E.A. Policy on the Reduction of Air Pollution

THE British Electricity Authority has stated that at its first meeting following the publication of the Beaver Committee's report, careful consideration was given to the views of that committee, and particularly to the proposal that gas washing should be introduced at all new power stations. The B.E.A. says that gas washing has a long history, and has been thoroughly explored by all parties, including the Government, the electricity supply industry and the public health interests. Despite the Beaver committee's views, it is by no means established, the B.E.A. claims, that gas washing can be effectively introduced and, moreover, the committee itself recognises that the complete removal of sulphur dioxide from power station gases would leave more than three-quarters of the sulphur problem unsolved. Certain technical considerations are discussed in the report, but there are many complicated factors which the Government and the British Electricity Authority will have to take into account in reaching their decisions. Whilst the B.E.A. finds some of the references in the report ambiguous, it says that it is submitting to the Government the relevant factors, including the heavy capital cost which, covering also further grit arresting installations, could not be less than £140 million, and might even reach £250 million within the next ten years. This, it is stated, together with the extra operating costs, would involve an increase of at least 12 per cent in the generation cost of electricity. Notwithstanding these considerations, the British Electricity Authority says that it is prepared to face the financial liability incurred in installing gas washing plant at power stations when it is satisfied, after consultation with the Government, that this is the right course to pursue on grounds of national interest and public health.

Smoke Pollution Observing Station

AN observing station for measuring the smoke and sulphur dioxide pollution in the London atmosphere has been established in the Science Museum, South Kensington, by co-operation with the Fuel Research Station of the Department of Scientific and Industrial Research. It is stated that the station is one of a number that are being established to permit a more detailed examination of atmospheric pollution in London and elsewhere. The sampling equipment is displayed as a working exhibit in the meteorology gallery of the Museum. The smoke particles are captured on filter paper through which air is drawn from just above Museum roof level, by a small electric pump. As a result, a grey stain appears on the filter paper, the intensity of which is a measure of the degree of smoke pollution. The same air is bubbled through a weak solution of hydrogen peroxide where the atmospheric sulphur dioxide is dissolved to form an acid solution, the strength of which is measured by standard chemical methods. Observations of smoke and sulphur dioxide pollution are made daily by a member of the Museum staff and are reported to the Fuel Research Station, which is in charge of the investigation.

Heavy-Oil Engine Working Costs

THE Report on Heavy-Oil Engine Working Costs and Performance (1953) was presented at the annual general meeting of the Diesel Engine Users Association held on Thursday, December 16th. The returns totalled ninety-one, an increase of six over last year, and included seventy-one from home and overseas electrical generating stations, eighteen from waterworks and two from marine installations. With regard to lubricating oil, the report notes an increase in the stations using anti-oxidant or heavy-duty oils. In the report Tables I and II set out in detail the heavy-oil engine costs per unit generated for thirty-five home stations and thirty-six overseas stations, separate sections dealing with mechanical injection engines, installations employing air-blast and mechanical injection units, and air-blast injection engines only, while a final group records totals and averages of the various sections. The costs per water-horse-power-hour for eighteen home stations are listed separately for mechanical injection engine installations and those using air-blast engines only in Table III. Technical particulars of the performance of the two marine installations are given in detail in Table V. Tabular statements in the report summarise the results from the home and overseas generating stations and from the waterworks installations.

Combined Tension and Torsion Machine for Relaxation Tests

By A. E. JOHNSON* and N. E. FROST*

Here we describe a machine by means of which complex stress relaxation tests at high temperature may be carried out. Relaxation tests may be conducted under combinations of tension loads up to 600 lb and torques up to 1000in-lb over a temperature range 20 deg. to 800 deg. Cent.

AT the Mechanical Engineering Research Laboratory, East Kilbride, a comprehensive investigation of the creep, plastic strain and relaxation properties of a number of typical engineering materials at temperatures corresponding to actual working ranges, is being made to provide basic data for the design of the many engineering machine elements which are subject to working conditions involving complex stress systems at elevated temperatures.

In this programme much progress has been made in the investigation of steady stress creep, and plastic strain, but that portion of the programme devoted to creep under relaxation conditions is only just about to be started.

The reason why this aspect of the work has been left until the last is twofold. First, creep under relaxation conditions may reasonably be supposed to be related in its characteristics to creep under steady stress conditions, and to be modified by the incidence and magnitude of any plastic strain occurring. Accordingly, it was thought logical to acquire a satisfactory background of knowledge of these two phenomena under complex stress conditions at high temperatures before embarking upon the investigation of complex stress relaxation.

Secondly, it has been thought by a considerable number of investigators that a relatively simple relation might exist between creep under steady stress conditions and under relaxation conditions. Examination of such proposed simple relations in the light of the results of steady stress tensile creep tests and tensile relaxation tests has failed to confirm the simplicity of the relation and has indicated the necessity for the treatment of the relaxation part of the programme as a new aspect of the work.

The machine described in the following paragraphs has accordingly been designed to enable such data to be acquired as will enable the various important design problems involving combined stress relaxation at high temperatures to be approached upon a rational analytical basis.

Description of Machine

During the last ten or fifteen years a small number of combined stress creep machines have been in operation at high temperatures in investigations performed both at the National Physical Laboratory and Mechanical Engineering Research Laboratory. These machines and the combined extensometer and torsion meter used with them have been described in previous publications, but since the relaxation rig about to be described is designed to operate in conjunction with these creep machines and strain meters, outline drawings of the combined stress creep machine and torsion meter are shown in Figs. 1 and 3 in order to facilitate reference throughout the following test.

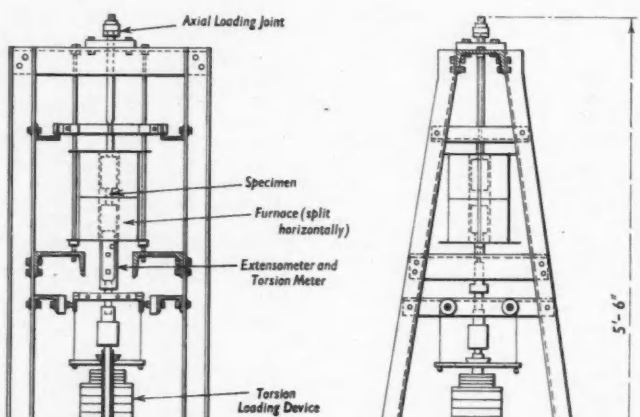

Fig. 1—Combined stress (tension and torsion) creep testing machine

Reference to Fig. 1 will indicate that the mode of loading the complex stress creep machine is such that the tensile load is applied to a scale pan at the base of a cylindrical shaft, the top of which is attached to the lower specimen† adapter through a simple, but quite effective universal joint. The torsion load is applied to a scale pan at the base of a relatively short tubular shaft which is suspended by wires from the torque arm of the machine, and which hangs concentrically with and around the shaft of the tension scale pan, thus ensuring the absence of extraneous movements which can arise from the use of two separate loading pans for the torsion rig.

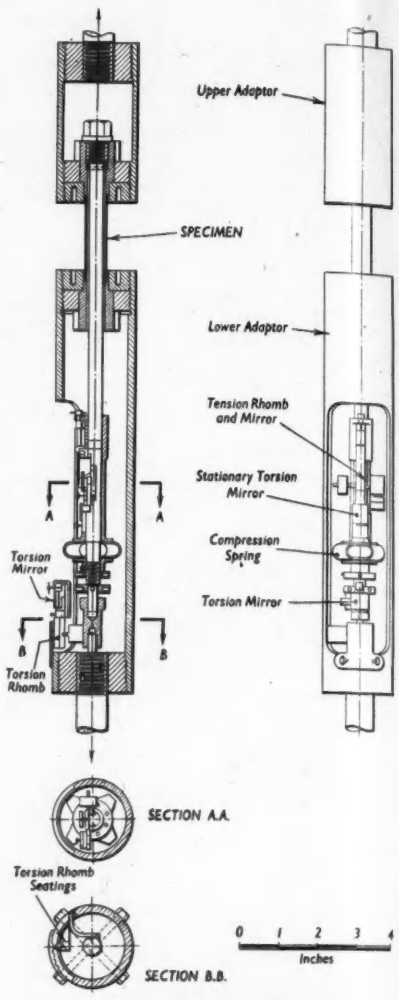

Fig. 3—Combined creep extensometer and torsion meter

For use with the relaxation equipment (Fig. 2) the tension scale pan is removed

† Thin walled tubular specimens are used.

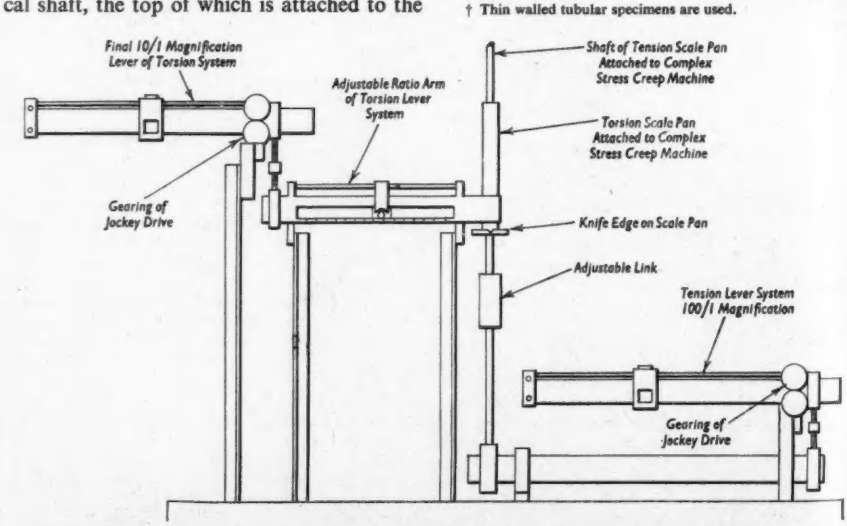
Final 10/1 Magnification Lever of Torsion System
Adjustable Ratio Arm of Torsion Lever System
Shaft of Tension Scale Pan Attached to Complex Stress Creep Machine
Torsion Scale Pan Attached to Complex Stress Creep Machine
Gearing of Jockey Drive
Knife Edge on Scale Pan
Adjustable Link
Tension Lever System 100/1 Magnification
Gearing of Jockey Drive

Fig. 2—General arrangement of loading system for complex stress relaxation machine

* Mechanical Engineering Research Laboratory, East Kilbride

from its shaft, which is then connected through an adjustable joint to the initial knife edge seating of a double lever system of 100 to 1 magnification which may be loaded by jockey weights of 1 lb moved by geared wheels and buttress thread, either hand or power driven. To these jockey weights extra fitting rider weights of up to a maximum of 5 lb may be added at will, giving a maximum load of 600 lb.

On the base of the torsion scale pan two knife edge seatings are fixed in line at either side of the shaft and along a diameter of the pan. Supported on these seatings is one knife edge of a lever pivoted at an adjustable knife edge and having at its farther end the initial knife edge of a 10 to 1 magnifying single lever system, loaded precisely as in the case of the tension lever system, and like that system including an adjustable link. The adjustable knife edge mentioned can be

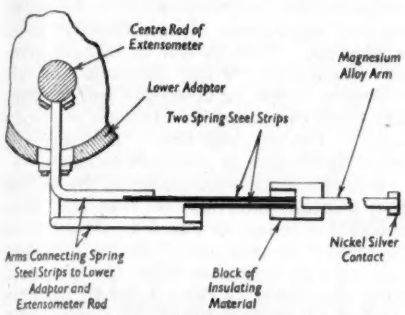
Centre Rod of Extensometer
Magnesium Alloy Arm
Lower Adaptor
Two Spring Steel Strips
Nickel Silver Contact
Arms Connecting Spring Steel Strips to Lower Adaptor and Extensometer Rod
Block of Insulating Material

Fig. 4—Plan view of strain controller for complex stress relaxation machine

moved from end to end of the 10in long lever, thereby altering the effective magnification of the torsion lever system as a whole and giving a maximum torque of about 1000in-lb.

By this means and by virtue of the two quite differing ranges of loading available on the two loading systems, a considerable range of tension to torsion stresses may be applied to the tubular specimen tested and this ratio of tension to torsion stress may be preserved while loading or unloading.

Owing to the fact that during relaxation tests the strain is retained constant, both levers tend to remain in their initial position; errors due to movement of levers are therefore inappreciable.

To conduct a relaxation test the jockey weights of the two lever systems, and the variable ratio arm of the torsion lever system are initially set to give the required ratio of tension to torsion stress in the test specimen. The two jockeys are then driven through their gearing at the same low speed of $\frac{1}{4}$ r.p.m. from the shaft of the same motor through a 1500 to 1 reduction gear.

The movement of the jockey by the motor is controlled from a strain controller (Fig. 4), comprising two spring steel strips of equal width but unequal lengths attached tangentially, respectively, to the extensometer rod and thereby to the upper end of the specimen, and to the outside of the lower adapter and thereby to the lower end of the specimen. The lower adapter is cut away to allow access to the extensometer rod. The two strips overlap each other for a portion of the length of the layer and are fixed together at their common end, carrying a magnesium arm having a nickel silver contact piece at its extremity. The device is operated in effect by the shear strain measuring elements of the combined extensometer and torsiometer, and is therefore unaffected in its operation by change of ambient temperature. Should the total shear strain of the specimen tend to alter then the relative movement of the spring steel strips results in a deflection laterally of the magnesium arm carrying the nickel silver contact piece. By suitable choice of strip dimensions very considerable magnification of movement can be obtained. The contact piece makes contact with a similar piece fixed on the machine framework, and through a suitable relay system closes the armature circuit of the motor operating the two jockey weights, the field of which motor is continuously excited. The motor then runs back the two jockey weights until the previous value of total shear strain is restored.

An armature brake prevents over-running. It is obvious that in the complex strain system in order to preserve all unit total strains constant it is sufficient to control the shear element of the total strain, and to unload (as does the mechanism described), preserving the initially imposed stress ratio.

All other unit strains may be expressed in terms of the stress ratio and either the axial or shear strain in both the elastic and creep conditions and this latter expression is independent of time and it is therefore only necessary to control either the axial or shear strain and retain the stress ratio constant. As between axial and shear strain the latter is the better choice inasmuch as it is unaffected by ambient conditions.

The use of the machine described opens up a new and wide field of research of great practical importance.

Clarification of Surface-Water Sewerage Theory

By L. B. ESCRITT, A.M.I.C.E., F.R.San.I., F.I.San.E.

No. I

In 1906 D. E. Lloyd-Davies described a method by which the run-off from sewered areas could be related to rainfall statistics, and surface-water and combined sewers could be designed without recourse to primitive rules of thumb. Some twenty-five years later modifications of the Lloyd-Davies method had been found necessary to allow for the shape of the catchment area or irregularity of distribution on impervious area. Then a number of new methods were devised, based on differing assumptions, and a lively controversy arose. To-day there is still incomplete agreement as to the methods which should be used or the basic assumptions to be accepted. There are also many misconceptions due to lack of knowledge of how the rainfall data were obtained and other causes. In particular, there is a not uncommon belief that the methods in use do not make due allowance for storage in sewerage systems. Here it is attempted to show how the differences of opinion arose, to clarify theory and to demonstrate how the effects of storage in sewers and tanks can be calculated.

Rainfall and Run-Off

In the nineteenth century rainfall run-off was estimated for sewerage purposes by allowing flat rates of rainfall. This, as we now know, led to over-sizing of sewers serving large areas and under-sizing of the smaller sewers. Emil Kuichling[1] was probably the first to appreciate the relation of duration of storm to intensity and to time of concentration of the catchment area, and also to anticipate the need for making special allowance for the shape of large catchments, as illustrated in the following passage :—

" . . . in drainage areas of moderate size, the heaviest discharge always occurs when the rain lasts long enough at its maximum intensity to enable all portions of the area to contribute to the flow. For large areas, on the other hand, a more elaborate analysis becomes necessary in order to find under what conditions the absolute maximum discharge will occur, . . ."

Development of this line of thought led to what is known in America as the " rational " system of surface-water sewer design, a system which is basically the same as that now accepted in this country, although, it is understood, lacking the improvements of theory that we have.

In Great Britain, design according to a " time of concentration " method originated with D. E. Lloyd-Davies[2] who, in his paper, " The Elimination of Storm-Water from Sewerage Systems," which was presented to the Institution of Civil Engineers in January, 1906, gave his findings based on a comprehensive series of rainfall and flow records.

For several years after Lloyd-Davies gave his paper, the majority of engineers continued to apply flat rates of rainfall, or to adhere to the early empiric run-off formulas. But in course of time the theory gained adherents until it had become a favourite topic and, in the early 1930s, a very active controversy arose as to the best method of making allowance for irregular shape of catchment area. Recently it has been remarked[3] that more has been written on this subject than on any other branch of municipal engineering ; and yet several misconceptions prevail.

During and since the controversy referred to, several valuable contributions were made to theory. But unsound hypotheses were also put forward, together with design methods, some of which, to say the least, were arbitrary or ill-considered. And among the originators of the sound proposals there were unreconciled differences of opinion. As a result there has been much divergence of practice and the most reasonable doctrines have not always been followed.

That such a state of affairs could exist in relation to a scientific study which has been a matter of importance to practical men and of interest to mathematicians may seem strange. But the peculiarity of the subject lies in the subtlety of its logic and the imperfections of the data to which the theories are applied. The purpose of these articles is to clarify existing theory by the elimination of the unsound and, where possible, by

Notation

Q_1—Rainfall run-off in cubic feet per minute.
Q_2—Discharge of sewer in cubic feet per minute.
Ap—Impervious area in acres.
R—Intensity of rainfall in inches per hour.
r—Inches of rainfall during T.
T—Duration of rainfall in hours.
t—Duration of rainfall in minutes.
t_c—Time of concentration in minutes.
N—Number of storms of this intensity occurring in ten years.
C—Storage capacity in cubic feet.
P—Outgo from storage in cubic feet per minute.
D—Diameter of sewer in inches.
L—Length of sewer in feet.
f—Fall of sewer in feet.

resolving the differences that exist between the sound theories.

The Lloyd-Davies Method

Briefly, the Lloyd-Davies theory is that the maximum run-off from a catchment occurs at the end of a storm the duration of which is equal to the time of concentration of the catchment—i.e. the time taken for water to flow from the farthest part of the catchment to the point of outgo. In the design of sewerage systems each component area is dealt with separately, the individual run-off being calculated in accordance with the individual area and time of concentration.

The Lloyd-Davies formula, simplified, reads :—

$$Q_1 = 60 \cdot 5ApR.$$

The value of R is determined according to a formula for storms of equal frequency of occurrence, it being found that the intensity of storms of equal frequency varies inversely as a function of the duration.

Impervious Area

The Lloyd-Davies formula requires knowledge of the area of the catchment and the intensity of rainfall.

The main source of error is in the estimation of impervious area. The present method is to measure the components of the gross area—roofs, roads, footpaths, garden land, &c.—and allow certain percentages of run-off for each so as to derive an impermeability factor for the whole. The impervious area is the gross acreage multiplied by the impermeability factor.

It is known that the proportion of rainwater that runs off a surface varies with the intensity of rainfall, the saturation of the ground by previous rainfall, the slope of the land, the height of surface above general level of the land, and other factors. In America allowances are made for some such factors, but current English practice is to adhere to stereotyped figures for impermeability which, incidentally, are mainly of American origin but of early derivation and uncertain accuracy. Should future research show that run-off varies regularly with any of the aforementioned factors, some modification of design theory might become advantageous. As far as English practice is concerned, this has not happened yet and this aspect of the subject will, therefore, not be further discussed herein.

There is, however, one relevant comment which must be made. Some engineers have expressed doubt as to the accuracy of the rainfall calculations by the Lloyd-Davies method and some, for the same reason, have made a practice of arbitrarily reducing the diameters of sewers so calculated. But if the size of a sewer is calculated by the Lloyd-Davies method or by any one of the sound modifications thereof, it is unlikely to be made larger than recognised practice intends, unless there has been an over-estimation of impermeability factor. If engineers want to be sure that they are being economical, they should carefully consider impermeability factors. This applies also to " time of entry " —i.e. the time taken for water to reach the sewer after running over the surface of the land.

Rainfall

Lloyd-Davies prepared his own rainfall statistics and evolved what is known as the Birmingham formula :

$$R = \frac{40}{t+20}.$$

According to his rainfall data, the curve plotted to this formula touched the curves for storms occurring once every two years and twice a year, and intersected at a number of points the once-a-year storm. Thus, it can be said that Lloyd-Davies allowed for storms likely to occur approximately once a year.

It appears that Lloyd-Davies's rainfall curve was not generally accepted : various engineers took to designing according to their own limited rainfall records, and in this way practice throughout the country became very diverse to such an extent that the Ministry of Health found it necessary to set up a Departmental Committee on Rainfall and Run-off[4] for the purpose of reaching some degree of uniformity of data to be adopted. This committee accepted the Birmingham formula for storms of twenty to 100 minutes' duration. But the evidence submitted by the Meteorological Office and examined by Leslie Roseveare showed that a modification was necessary for storms of five to twenty minutes' duration, which were found to conform reasonably with a curve plotted to the equation :

$$R = \frac{30}{t+10}.$$

The committee observed that their standard curve did not include all storms liable to occur and therefore recommended that the " excepted " storm might be regarded as provided for by the margin of safety that usually exists, e.g. storage capacity, permissible surcharge and excess of actual size of pipe over theoretical requirement.

The committee observed also that their conclusions might need to be reconsidered at a later date when more prolonged rainfall records were forthcoming, and that it did not appear desirable to suggest maximum or minimum curves which might be interpreted too rigidly. Unfortunately, the more recent tendency of engineers has been, contrary to the committee's recommendation, to adhere rigidly to the " Ministry of Health Standard Curve " and to ignore the more accurate and confirmed rainfall data that are now available.

Unlike the Ministry of Health Departmental Committee, the American authorities did not arbitrarily exclude a few storms of exceptional intensity, but, in most instances, recommended a design curve based on a family of storms of equal frequency of occurrence—an obviously logical approach to engineering design. Data for the preparation of such curves became available in Great Britain when Bilham produced his formula[5] :

$$N = 1 \cdot 25T(r+0 \cdot 1)^{-3 \cdot 55}$$

The accuracy of this formula was confirmed by D. J. Maclean,[6] who prepared a formula for world conditions which, when applied to the English once-a-year storm, gave a curve closely approximating to Bilham's curve.

The Ministry of Health standard curve lies reasonably close to Bilham's curve for the storm liable to occur once a year, crossing it at one point and elsewhere varying from it irregularly. It would thus appear to be reasonable to accept for design purposes Bilham's " once-a-year " storm in lieu of the Ministry of Health curve.

There is, however, one difficulty—Bilham's formula is inconvenient for general use. For this reason the new formula :

$$R = \frac{5 \cdot 9}{t^{\frac{8}{9}}},$$

was suggested as a substitute because, containing no plus or minus signs, it made easy a number of calculations which otherwise would have been very difficult. This formula was found to vary immaterially from both Bilham's and Maclean's curves.[7] It is used in various calculations for run-off and storage which follow.

It should be pointed out that, apart from being based on inadequate data and producing an inconsistent curve, the Ministry of Health formula is dangerous in one respect—it cannot be extrapolated. But it has been extrapolated by many designers, and gross inaccuracies have resulted. On the other hand, Maclean's, Bilham's and the writer's curves can be applied to storms of all durations likely to occur in the most extensive sewerage practice.

Bilham's Statistics

The method by which Bilham's rainfall statistics were prepared needs to be known for the significance of the statistics to be understood. This, as will be seen, becomes of importance when methods of the " tangent " type are compared with methods like those originated by Coleman and Johnson, or Ormsby and Hart. It could have other significance in new circumstances.

Bilham's data were collected by finding the shortest intervals of time in which specified amounts of rain fell. This did not mean that the measured " storms " included any rainfall before or after the period of time applicable to the specified intensity. Also, a storm was considered as one storm even if there was a temporary cessation of rainfall between the beginning and the end. This investigation was applied to ten years' records.

From the data obtained and expressed by Bilham's formula, it is possible to estimate the number of days in a period of years on which so many inches of rain are liable to fall in so many minutes, and curves can be plotted for the " once-a-year " storm, once-in-five-years storm, once-in-ten-years storm, &c. The description, however, of a curve as the " once-a-year " curve does not mean that storms complying with the curve will occur on the average only once a year. If a particular point on the curve is considered, it can be implied that, on the average, a storm of that intensity will occur once a year. But the rainfall station will also record other storms complying with the curve. For example, a storm of about 1·4in per hour lasting for ten minutes may be recorded ; but also on the same or another occasion there may be a precipitation of about 0·9in per hour lasting for twenty minutes. Thus, when the whole curve is considered, the number of " once-a-year " storms that occur during the year and complying with the curve must exceed one, but just how many cannot be said at present, for this matter has not been investigated.

The once-a-year storm is not a single storm which, like Professor Ormsby's hypothetical storm, complies throughout its duration with the curve. Inspection of rainfall records shows that while one once-a-year storm complies with the curve for a short period only, being short and intense, another may consist of a prolonged period of rainfall enclosing a sharp peak, and yet another may comply with the curve in two places with a gap between. On rare occasions only intensity may just exceed the requirements of the curve for a considerable period as would be required to produce Ormsby's hypothetical storm.

In addition to obtaining and analysing the data, Bilham did valuable work in his advice as to how they should be used and the

following quotations from his paper should be known to all :—

"A vast mass of accurate observations has been 'boiled down' in order to arrive at the results now presented, and these facts are, or ought to be, of particular interest to drainage engineers who are professionally concerned with matters relating to the incidence of heavy rainfall."

On the important matter of whether or not a general rainfall curve or local statistics based on limited data should be used, the following paragraph is of significance :—

"The really intense rains lasting no more than an hour or two seem to be distributed without regard to the average annual rainfall. On the evidence available up to the present, he would be a bold man who would base designs involving large capital expenditure on the assumption that his particular area was less subject to intense rainfall than the hypothetical 'average station' to which our calculations apply. . . .

"I now wish to suggest that it may not altogether be wise to base everything on purely local observations. One thing is very clear, namely, that the incidence of heavy rains in short periods is very fortuitous. A particular area may for years enjoy an apparent immunity from intense rain as compared with some neighbouring district, but there is good reason to believe that in the majority of cases such immunity is due to pure chance rather than to real climatological characteristics."

The choice of design storm should be determined by comparative estimation of cost of sewerage works and of damage that would result from flooding if this were reasonably practicable. This has never been done and consequently there is considerable variation of practice throughout the world. In England an approximation of the once-a-year storm is usual : but in the United States storms occurring as infrequently as once in ten or fifteen years have been allowed for.

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[5] E. G. Bilham : "Classification of Heavy Falls in Short Periods." *British Rainfall*, 1935.
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(To be continued)

Calculation of Losses in Transformer Cores

By A. LANGLEY MORRIS, M.I.E.E.

No. I—CORES WITHOUT BOLT HOLES OR SLOTS

The normal method of core loss calculation is based on the assumption of a uniform flux distribution throughout the core. Such a procedure can unwittingly lead to core constructional faults which cause higher losses and these increased losses can easily be ascribed to a poor batch of material or to faults arising during the building of the core. It is therefore desirable to have available a rigorous method of calculating the losses in transformer cores. Expressions are developed in this article which take account of the non-uniformity in the flux distribution across the face of the core plates. Non-uniformity can and does occur across the stack of the plates, one cause is the interleaving of the plates, but this third dimensional effect is not considered.

NON-UNIFORMITY in the flux distribution across transformer core plates occurs for two main reasons ; first, because the iron path increases from the window perimeter to the outside perimeter of the core, and, secondly, because of obstructions such as bolt holes. There is another possibility—that of anisotropy of the core material, but this has not been taken into account.

It is known that, for ordinary magnetic material operated over the usual flux densities, the watts loss can be taken as proportional to the square of the flux density. The expressions in this article are based upon such a quadratic relationship. Transformer cores often consist of a series of magnetic paths. Series paths are best expressed in terms of a complex reluctivity, $H/B=r+jx$, r being responsible for the inductance and x for the loss. MacFadyen[1] has shown that x (which he designates ψ) is relatively constant over a wide range of flux densities and accounts for the quadratic relationship. The loss reluctivity is x multiplied by the geometrical reluctance of the core, so the general expression for the core loss can therefore be expressed :

$$W=P\,.\,S \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where

W=core loss in watts.
P=loss in a rectangular stack of core plates.

and

S=geometrical reluctance of the core face.

The loss reluctivity constant x is contained in the watts per kilogramme, so its value need not be known. If the watts per kilogramme at a flux density $B_1=w_1$ (obtained from the data for the magnetic material), then for a stack of plates of dimensions $g\times g\times b$ having a flux density B_1 :

$$P=\frac{pqbw_1g^2}{1000} \quad . \quad . \quad . \quad . \quad (2)$$

with

p=stacking factor of the plates.
q=density for the core material,

all dimensions being in centimetres.

THE LOSS IN A TOROIDAL CORE

The flux distribution across the face of the toroidal core illustrated in Fig. 1 is non-uniform because the iron path reluctance progressively increases with the radius.

If the flux density is assumed to have a uniform value of B_1, then assuming the iron width g is r_2-r_1, and the path length is $\pi(r_2+r_1)$, then the loss :

$$W=PS_1 \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where

$$S_1=\frac{\pi(1+\Delta_1)}{1-\Delta_1} \quad . \quad . \quad . \quad . \quad (3a)$$

and

$$\Delta_1=\frac{r_1}{r_2}.$$

The flux is not uniformly distributed so that the loss will be

$$W=\frac{P}{g^2}\,.\,2\pi\int_{r_1}^{r_2}\left(\frac{B_x}{B_1}\right)^2 x\,dx \quad . \quad . \quad . \quad (4)$$

where

$$B_1=\frac{4\pi}{10}\,\frac{IN\mu}{\pi(r_2+r_1)}$$

B_x=flux density at $x=\frac{4\pi}{10}\cdot\frac{IN\mu}{2\pi x}$.

IN=exciting ampere turns.

and

μ=permeability.

It can be verified, therefore, that equation (4) becomes

$$W=PS_2\,\frac{IN\mu}{\pi} \quad . \quad . \quad . \quad . \quad (5)$$

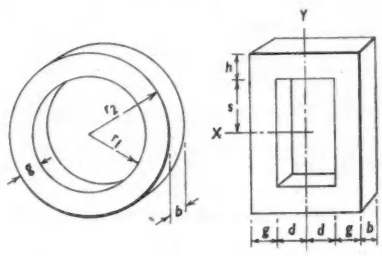
where

$$S_2=\frac{\pi}{2}\left(\frac{1+\Delta_1}{1-\Delta_1}\right)^2\log\frac{1}{\Delta_1} \quad . \quad . \quad (6)$$

The following table gives the values of S_1/π and S_2/π as functions of Δ_1 :

Δ_1	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
S_1/π	1·22	1·5	1·86	2·33	3·0	4·0	5·67	9·0	19·0
S_2/π	1·41	1·82	2·07	2·48	3·13	4·08	5·75	9·1	19·1

For the usual values of r_1/r_2 the difference between equations (3) and (5) is negligible



Figs. 1 and 2—Toroidal and rectangular cores

and the flux can be considered to be uniformly distributed.

THE LOSS IN A SINGLE-PHASE RECTANGULAR CORE

For the type of core shown in Fig. 2, the conclusion of the previous section will not be correct owing to the influence of the corners. If the flux were uniformly distributed, with the yoke flux density constant even to the corners, the loss would be :

$$W=\frac{4P}{w_1g^2}[gs\,.\,w_1+(hd+hg)w_2] \quad . \quad . \quad (7)$$

Where

w_1=watts per kilogramme in the limbs

and

w_2=watts per kilogramme in the yokes

but from the quadratic relationship

$$w_2=\frac{g^2}{h^2}w_1$$

so that (7) becomes

$$W=4PS_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

with

$$S_2=\frac{s}{g}+\frac{d}{h}+\frac{g}{h} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

The correct geometrical reluctance for the actual non-uniform flux distribution is a field problem with the boundary conditions the same as the core face of Fig. 2. Thus, a solution is required for Laplace's equation :

$$\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}=0.$$

The most suitable method, when the boundaries can be expressed in rectangular co-ordinates, is that of the Schwarz and Christoffel transformation.[2] The magnetic field is expressed as $\phi+j\psi$, where ϕ is the magnetic potential and ψ the flux. With these magnetic quantities the loss may be written :

$$W=4C(\phi_1-\phi_2)\psi \quad . \quad . \quad . \quad . \quad (10)$$

From reasons of symmetry $\phi_1-\phi_2$ is the magnetic potential difference between the dotted lines X and Y of Fig. 2. The value of ψ can arbitrarily be given the value of unity, with the result that :

$$W=4C(\phi_1-\phi_2) \quad . \quad . \quad . \quad . \quad (10a)$$

Equation (10*a*) must, however, be equal to equation (1). It may be found that the solution of a field problem by means of

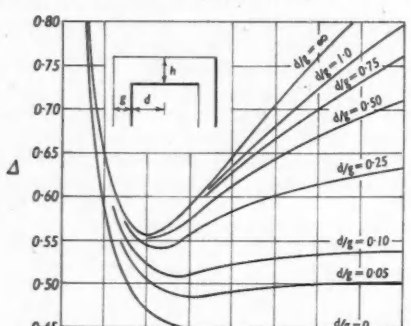


Fig. 3—Correction factor for corner

Schwarz and Christoffel transformations, where the value of ψ is unity, gives the ϕ terms of (10*a*) in the form of a geometrical reluctance :

$$\phi_1-\phi_2=S_4=\frac{s}{g}+\frac{d}{h}+\Delta_2 \quad . \quad . \quad (11)$$

The only difference between equations (9) and (11) is that g/h is replaced by a quantity Δ_2. Therefore, in (10*a*) $C=P$ and

$$W=4P\left\{\frac{s}{g}+\frac{d}{h}+\Delta_2\right\} \quad . \quad . \quad (12)$$

The quantity Δ_2 should be a function of the core dimensional ratios s/g, d/g and h/g, but numerical values involving three variables would be extremely difficult to work out. The conclusion for the toroidal core indicates that the influence of the radial non-uniformity is not serious, and it is reasonable to assume that the ratio s/g has little effect on Δ_2. Furthermore, in practice the dimension s is much larger than the others so one can well assume that along the line X of Fig. 2, the flux in the core is uniformly distributed. Now with but two ratios, d/g and h/g, it is possible to produce curves for Δ_2 with h/g as the variable and d/g as the parameter. Such curves are shown in Fig. 3 and their derivation is given in Appendices 1, 2 and 3.

The two limiting values for the parameter are $d/g=0$ and $d/g=\infty$. The former condition does not arise in transformer problems, since this would imply no window space : the latter condition is that of a very wide window, and it will be found that this is the general condition for most practical cases. It means that the flux is almost always uniform along the line Y of Fig. 2.

Since it is often the practice to obtain a reduced core loss by increasing the yoke ratio h/g, it is useful to know the utmost reduction that is thereby possible, this occurs for an infinite yoke height, i.e. $h/g=\infty$. Under this condition the ratio d/g becomes important and $d/h=0$. The loss is therefore :

$$W=4P\left\{\frac{s}{g}+\Delta_3\right\} \quad . \quad . \quad . \quad (13)$$

with Δ_3 shown as a function of d/g in Fig. 4, the derivation of the curve being given in Appendix 4.

In order to see the difference between the loss as calculated by equations (8), (12) and (13), an example is shown for three different yoke heights. The quantity P being a common factor in all three equations, it is only necessary to work out the geometrical reluctance to show the loss variation.

If a single phase rectangular core has $s=20$in, $g=10$in and $d=5$in, the yoke height being 10in, 15in or ∞, then the geometrical reluctances are shown in the two tables :—

CASE A—*Uniform Flux Distribution, Equation* (9)

Yoke height : h	10in	15in	∞
s/g	2	2	2
d/h	0·5	0·33	0
g/h	1·0	0·67	0
Reluctance S_3	3·5	3·0	2·0

CASE B—*Correct Flux Distribution, Equations* (12) *and* (13)

Yoke height : h	10in	15in	∞
s/g	2	2	2
d/h	0·5	0·33	0
Δ	0·56	0·57	0·83
Reluctance S_4	3·06	2·9	2·83

Calculations based on a uniform flux would lead to the erroneous conclusion that an increase in yoke height is well worthwhile. It is perhaps as well to add a warning here that the present analysis takes no account

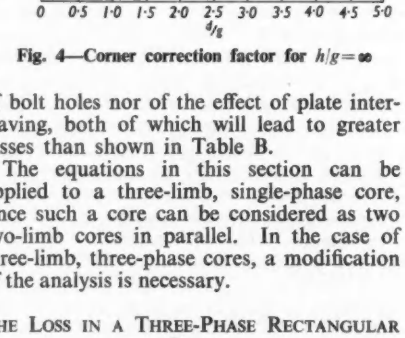


Fig. 4—Corner correction factor for $h/g=\infty$

of bolt holes nor of the effect of plate interleaving, both of which will lead to greater losses than shown in Table B.

The equations in this section can be applied to a three-limb, single-phase core, since such a core can be considered as two two-limb cores in parallel. In the case of three-limb, three-phase cores, a modification of the analysis is necessary.

THE LOSS IN A THREE-PHASE RECTANGULAR CORE

If a uniform flux distribution were assumed for the three-phase core shown in Fig. 5, then the loss would be given by :

$$W=\frac{4P}{g^2w_1}\left\{6sgw_1+8dhw_2+6hgw_2\right\} \quad . \quad (14)$$

but since $w_2=\frac{g^2}{h^2}w_1$,

then (14) becomes :

$$W=4P\left\{\frac{3}{2}\frac{s}{g}+2\frac{d}{h}+\frac{3}{2}\frac{g}{h}\right\} \quad . \quad . \quad (15)$$

In order to find the modified geometrical reluctance for the actual flux distribution, it is first necessary to know the three-phase flux conditions in the yokes.

The flux flowing in the limbs of Fig. 5 is shown as ψ_A, ψ_B, and ψ_C in Fig. 6. From this vector diagram :

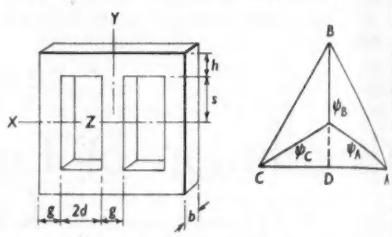
$$\psi_A=\frac{\psi_B}{2}(j+\sqrt{3}) \text{ and } \psi_C=\frac{\psi_B}{2}(j-\sqrt{3}).$$

The three-phase flux can therefore be resolved into two single-phase fluxes ψ_α and ψ_β at right angles to one another.[3] The α flux flows up one limb (say the centre limb) and returns via the other two limbs. The β flux flows round only two of the limbs (say the outer two).

The core loss can be found for each flux condition, the total loss being the sum of the α and β losses.

In the field analysis for the single-phase core the flux ψ was made unity, so that if the curves of Fig. 3 are to hold for three-phase conditions then $\psi_\alpha=1/2$ and $\psi_\beta=\sqrt{3}/2$.

The α Loss.—The loss determination is that for a three-limb, single-phase core, but with a modification of the magnetic potential



Figs. 5 and 6—Three-phase rectangular core and flux conditions

as a consequence of the flux being $\frac{1}{2}$. From considerations of symmetry the potential drop from X to Z of Fig. 5 is required, and so the loss.

$$W_\alpha=4P(\phi_{\alpha X}-\phi_{\alpha Z})\tfrac{1}{2} \quad . \quad . \quad . \quad (16)$$

The three-phase core, however, differs from a three-limb, single-phase core in that all three limbs have the same width g. Therefore, for one corner Δ_2 is a function of h/g, and for the other corner of $2h/g$. In Fig. 3, the curve $d/g=\infty$ should be used, since the other ratios of d/g have been derived for symmetrical limbs which is not so for this α flux condition.

As the flux is now $\frac{1}{2}$, the potential drop will be $\frac{1}{2}$ that for the single-phase case and it may be verified that :

$$\phi_{\alpha X}-\phi_{\alpha Z}=\tfrac{1}{2}\left\{\frac{s}{g}+\frac{d}{h}+\Delta_a+\frac{2s}{g}+\frac{d}{h}+\Delta_b\right\} \quad . \quad (17)$$

where Δ_a and Δ_b are given in Fig. 3 for h/g and $2h/g$, respectively, $d/g=\infty$ for both cases.

The β Loss.—From consideration of symmetry, the magnetic potential between X and Y is required, the flux path including one corner and a T junction. The β flux has a value of $\sqrt{3}/2$ so that the β potential is $\frac{\sqrt{3}}{2}$ of the equivalent single-phase potential. The β loss for the core is therefore :

$$W_\beta=4P(\phi_{\beta X}-\phi_{\beta Y})\frac{\sqrt{3}}{2} \quad . \quad . \quad (18)$$

and

$$\phi_{\beta X}-\phi_{\beta Y}=\frac{\sqrt{3}}{2}\left\{\frac{s}{g}+\frac{2d}{h}+\Delta_a+\Delta_c\right\} \quad . \quad (19)$$

where Δ_a is the same as for the α flux, but

$$\Delta_c=g/2h-\Delta_4 \quad . \quad . \quad . \quad . \quad . \quad (20)$$

Fig. 7 gives Δ_4 in terms of $g/2h$, and is based on the assumption that both d/g and

s/g are infinitely large, as may be seen from the derivation given in Appendix 5. Note that this correction is relatively small, i.e. little flux bulging taking place.

The Total Three-Phase Loss.—This is the sum of the α and β losses and is :

$$W=4P\left\{\frac{3}{2}\frac{s}{g}+2\frac{d}{h}+\Delta_a+\frac{1}{4}\Delta_b+\frac{3}{8}\frac{g}{h}-\frac{3}{4}\Delta_4\right\} \quad \ldots\ldots (21)$$

The difference between the loss as calculated by equations (15) and (21) may best be

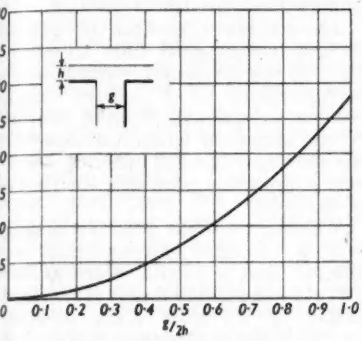


Fig. 7—Correction factor for " T " joint

seen from an example, in which the core dimensions have been made the same as for the single-phase case in the previous section :

CASE A—*Uniform Flux Distribution Equation* (15)

Yoke height : h	10in	15in
$3/2\ s/g$	3·0	3·0
$2d/h$	1·0	0·67
$3/2\ g/h$	1·5	1·0
Geometrical reluctance	5·5	4·67

CASE B—*Correct Flux Distribution Equation* (21)

Yoke height : h	10in	15in
Δ_a	0·56	0·59
$\frac{1}{4}\Delta_b$	0·16	0·19
$\frac{1}{8}\ g/h$	0·38	0·25
$\frac{3}{4}\Delta_4$	0·06	0·03
Geometrical reluctance	5·04	4·67

Again the correct loss calculation shows that the improvement in loss by an increase in yoke height is not so great as anticipated from a uniform flux calculation.

APPENDICES

(1) *The Ratio of* $\frac{\text{Window Width}}{\text{Core Width}}$, *Large, i.e.* $d/g=\infty$.—The field problem is the same as that considered by Thomson,[4] Jeans[5] and others so that there is no need to give the mathematical analysis. It may be verified that :

$$\phi_1=\frac{s}{g}+\frac{2h}{g}\tan^{-1}\frac{g}{h}+\log\frac{1}{4}\left(1+\frac{g^2}{h^2}\right)$$

$$\phi_2=\frac{d}{h}+\frac{2g}{h}\tan^{-1}\frac{h}{g}+\log\frac{1}{4}\left(1+\frac{h^2}{g^2}\right)$$

and

$$\Delta_2=\frac{2h}{g}\tan^{-1}\frac{g}{h}+\frac{2g}{h}\tan^{-1}\frac{h}{g}+\log\frac{1}{4}\left(1+\frac{g^2}{h^2}\right)\left(1+\frac{h^2}{g^2}\right)$$

(2) *The Ratio* $d/g=0$.—This condition never arises with transformer cores, but does arise in other problems. For example, in the determination of the electrostatic capacity of a thin plate in a rectangular tube. The curve of $d/g=0$ has been included in Fig. 3 for the sake of completeness.

The Schwarz and Christoffel transformation is :

$$\frac{dZ}{dt}=\frac{At}{(t^2-1/k^2)^{\frac{1}{2}}(t^2-1)},$$

yielding upon integration and with the appropriate constants,

$$Z=\frac{2g}{\pi}\log\cdot\frac{k'+(1-k^2t^2)^{\frac{1}{2}}}{(1+k')(1-t^2)^{\frac{1}{2}}}$$

where

$$k'=(1-k^2)^{\frac{1}{2}}$$

The potential function is :

$$\phi+j\psi=\frac{1}{\pi}\log\frac{1-t}{1+t}.$$

If the algebraic operations are performed in the usual manner as given by Jeans[5] then it may be found that :

$$\phi_1-\phi_2=\frac{s}{g}+\frac{2}{\pi}\log\frac{1+k'}{k'}$$

and

$$\frac{h}{g}=\frac{2}{\pi}\log\frac{1+k'}{k},$$

from which

$$\Delta_2=\frac{1}{\pi}\log\frac{4e^{\pi g/h}}{e^{\pi h/g}-1}.$$

(3) *The General Case of* d/g *Finite in Value.*—A formal solution of this field problem has been given by Cockcroft,[6] but he has only given numerical values of Δ_2 for the particular case of $h/g=1\cdot0$. In order to find numerical values for other ratios of h/g, it is necessary to transform Cockcroft's solution into a form suitable for use with the tables of elliptic functions published by the Smithsonian Institute.[7] The algebraic work is fairly considerable and is therefore omitted, but for the benefit of anyone who is interested all the necessary elliptic equations can be found in Cayley's[8] classical work and in the Smithsonian publication. It may therefore be verified that :

$$\frac{d}{g}=\frac{h}{g}\cdot\frac{K'}{K}-\frac{r}{90}$$

$$\frac{h}{g}=\frac{2K}{\pi}\left\{\frac{A(r)\,.\,C(r)}{B(r)\,.\,D(r)}-E(r)\right\}$$

and

$$\Delta_2=\frac{h}{g}\left\{1-\frac{r}{90}\right\}-\frac{d}{h}+\frac{2}{\pi}\log\frac{(\cos\theta)^{\frac{1}{2}}}{A(r)\,.\,B(r)\sin\theta}$$

Where $A(r)$, $B(r)$, $C(r)$, $D(r)$ and $E(r)$ are Smithsonian elliptic functions of modulus $k=\sin\theta$ of amplitude $\phi=r$.

K and K' are the complete elliptic integrals to the same moldulus.

Since it is necessary to determine the dimensional ratios by first assuming values for r and k, the numerical work required to derive the curves in Fig. 3 for $d/g=0\cdot75$, $0\cdot5$, $0\cdot25$, $0\cdot1$ and $0\cdot05$, is fairly considerable.

(4) *The Case of* $\frac{\text{Yoke Height}}{\text{Limb Width}}$, *Large, i.e.* $h/g=\infty$.—The field solution has been given by Thomson,[4] and it may be verified that :

$$\phi_1-\phi_2=\frac{s}{g}+\Delta_3.$$

Where

$$\Delta_3=\frac{1}{\pi}\left\{\frac{d}{g}\log\left(1+\frac{2g}{d}\right)+2\log\left(2+\frac{d}{g}\right)\right\}$$

(5) *The Flux Bulging Factor* Δ_4.—The field problem of a T-junction is similar to those considered by Thomson[4] and by Carter.[9] Thus, for a yoke of length $(2d+g)$ and height h joined in the middle by a limb of length s and width g. The magnetic potential difference between A and B (the ends of the yoke) may be found to be :

$$\phi_A-\phi_B=2\left\{\frac{d}{h}+\frac{g}{2h}-\Delta_4\right\}$$

where

$$\Delta_4=\frac{1}{\pi}\left[\frac{g}{h}\tan^{-1}\frac{g}{2h}-\log\left\{1+\left(\frac{g}{2h}\right)^2\right\}\right]$$

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(*To be continued*)

Glass Fibre Reinforced Plastics in the Chemical Industry

By FRANCIS F. JARAY, Dr.-Eng. (Vienna), M.I. Chem. E.

No. I

The problem of corrosion in the chemical industry is gradually getting more difficult. The emergence of new plastic materials which can be shaped easily has given rise to methods of construction of chemical equipment which are both simple and comparatively inexpensive. We are only now beginning to understand the problems connected with the use of these materials, and the methods of construction, after some very serious difficulties in the beginning. This article gives further details of materials and methods and notes on some successful applications.

AN urgent need of the chemical industry, as far as materials of construction are concerned, are substances which combine mechanical strength with good chemical resistance, especially at high temperatures. Freedom of sensitivity to small impurities as well as resistance to erosion and stress corrosion is important. There are very few metals available which will answer these requirements fully, and under adverse conditions most of them will only be suitable for a given space of time. This is the reason why plastics have found such a rapidly increasing scope as materials for construction. Especially rigid P.V.C. has found a very large field of application, limited mainly by its inability to stand elevated temperature, i.e. temperatures above 40 deg. Cent. or in some cases 60 deg. Cent. For higher temperatures the asbestos-filled phenolics and furanes have had the field largely to themselves.

The advent and development, during the war, of glass fibre reinforced plastics of the polyester group, mainly for the aircraft and shipbuilding industries, was therefore welcomed by the chemical industry. It was taken as a promise that materials would now be available with a temperature resistance of well in excess of 100 deg. Cent. or even up to 150 deg. Cent. The mechanical strength of these laminates was measured on new samples which had neither been exposed to liquids, humidity or temperature. The resins themselves were tried in the laboratory and were found to have good chemical resistance. Then the same story which had originally happened with rigid P.V.C. happened again with glass fibre polyester lami-

nates. They were used with insufficient data to go on for the wrong purposes, and under wrong conditions. A number of technical failures followed with some very serious economical consequences for a few firms in America, where the advent of the glass fibre laminates for the chemical industry had been welcomed with superlative descriptions. It is only now, after a quite considerable setback, that the difficulties are recognised and that it has become possible to tackle some problems satisfactorily.

The following paragraphs are intended to give a short description of materials and available methods, and descriptions of a few practical solutions of the ever-growing problems.

Binders

Whilst potentially a very considerable number of resins are suitable for reinforcement with glass and other fibres, mainly the following six have so far been successfully used in this manner. As their chemistry has already been described elsewhere, it may be sufficient to mention them briefly :—

(1) The group of polyester resins which embraces a very considerable and ever-increasing number of combinations of chemical compounds, (2) the epoxide resins, (3) the phenolic resins, (4) the furane resins, (5) the silicone resins and, (6) the fluocarbon resins.

The polyester resins are at present the most widely applied materials, their chemical resistance is promising and at present they will withstand weak acids and very weak alkalies (pH under 10). They are resistant to solvents and are available in a very large number of viscosities which is important from the point of view of manufacturing, and can be adjusted in such a manner that they will give materials which range over a very wide scale of final hardness. They are available also with a very wide range of setting temperatures and pot lives and can be used for every known method of fabrication from wet lay-up to high-pressure moulding.

The epoxide resins which have been introduced recently are, like the polyester resins, available for every known technique of manufacturing. They are marked by an exceedingly high degree of adhesion to glass and glass fibres and have the smallest coefficient of shrinkage of all known resins. Their chemical resistance is very much better than that of the polyester resins and their resistance to solvents is outstanding.

Phenolic resins are nearly the oldest of all synthetic resins. They have been somewhat neglected in connection with glass fibre reinforced plastics. Their chemical resistance against acids and solvents is equal to or better than that of the epoxide resins, especially at elevated temperatures. Their resistance to alkalies is very much inferior. In spite of their very much lower price they have not been able to gain a footing in the field of glass fibre reinforced plastics which is probably due to the fact that they are available in dark brown and black only, and that their adhesion to glass is not very good and their shrinkage quite considerable, with the result that the final article will only have something like one-quarter to one-sixth of the mechanical strength of the epoxide resin laminates.

Furane resins are quite probably, due to their universal chemical resistance, the most promising of all laminating resins for the chemical industry. Financially the material stands between the polyesters and epoxide resins, but has a drawback like the phenol resins, in that it is only available in black. Before very much progress can be made with it, a suitable surface treatment material or method for the glass fibre will have to be developed. For, though a furane resin will bond very strongly on many surfaces, including glass, in fact very much better than phenolics, this problem in the laminating field has not yet been completely mastered. The result is that furane laminates, at present, cannot compare in strength with polyester or epoxide laminates, but their outstanding all-round chemical performance, especially at elevated temperatures, should go a very long way to make up for this.

Silicones provide a most expensive bonding material with good heat resistance, but a generally poor all-round chemical performance. However, its advantages are exactly where the furane and, incidentally, most other resins fail : it is resistant to oxidising liquids like chromic acid or nitric acid, and can therefore be advantageously used for this purpose. However, just for these acids generally, there are metals available which will do the job quite satisfactorily and this, combined with high price, will undoubtedly put a limit to the usefulness of silicone laminated glass fibre.

The fluocarbons P.T.F.E. and P.T.F.C.E. are well known as the two plastic materials which will not be attacked by any known chemical other than molten alkali metals, and, under certain conditions, by fluorine gas. As a consequence, these materials have been generally used for laminating glass fibres for the making of pipes and hoses where inertness and reliability of performance was required.

Reinforcements

Of the man-made fibres used for laminating purposes in the chemical industry glass fibres are nearly exclusively used. It is necessary to replace the glass fibres with others only when the piece of equipment produced has to deal with hydro-fluoric acid or fluor compounds. Orlon, an acrylo nitrile fibre has proved itself quite satisfactory for this purpose.

Glass fibres are available for the laminator in a number of forms which are described in greater detail elsewhere in this article. In short, they can be woven from twisted (thrown) fibres and woven into plain weaves, satins, leno or mock-leno weaves as well as special unidirectional weaves. Lately, it has become possible to weave untwisted bundles (rovings) which is a very sensible step forward to obtain higher reinforcement efficiency.

Glass fibres are also available in the form of mats. These can either be so-called chopped mats, where fibre bundles of approximately 2in length lie flat with a random distribution of direction, or in the form of diamond mats where the fibre bundles lie preferably in one direction. The old form of mat, where very thin fibre bundles or even individual fibres were arranged predominantly in one direction, is not frequently used. This is very regrettable, as it is, as will be explained later, a most suitable material for the obtaining of a great reinforcing effect.

Rovings, the third form in which glass fibres are available, are long strands of glass fibre bundles—not, or hardly, twisted—with varying numbers of glass fibres in the bundle. For reinforcement purposes, especially for ducts and pipes, they are a most important material. For many purposes they are chopped up and used in preforms, in the "matched mould" system of shaping. This has for the chemical industry only comparatively very small importance as it requires a fairly substantial run of production which generally does not exist in a field where nearly every piece of equipment is specially made or "custom built."

The greatest difficulty in producing a satisfactory laminate is caused by the various layers covering the glass fibre which impede the proper bonding of the resin to the actual glass surface. In the case of woven glass fibres this layer is caused by the size, a material which is applied to the glass fibres during manufacture to prevent the crossing bundles from haltlessly sliding upon each other and preventing the proper formation of the woven material.

There exists a number of methods of treating woven glass fibre to remove the size. It can be simply washed with water or detergents, or it can be heat-treated without or with a following treatment by certain chemicals which will combine with the glass and the well-adhering water skins and so provide a good base for the bonding of the resin.

Whilst glass fibres generally undergo not only a treatment leaving their surfaces covered with a material which stands in the way of bonding, they are, as demanded by the nature of the glass itself, covered with extremely well-adhering water "skins." These water skins generally are not very harmful, as fibre mats are never required where the highest efficiency of the reinforcement is needed. It is, however, very important to remove them when working with rovings as the skins are an important factor affecting the permanent strength of the reinforced glass fibre laminate. It must be added that even the best surface treatment will only be effective as long as water will not penetrate the resin and again attach itself to the glass. It must be stated frankly that there is at present not yet available any data which will shed any light on the permanent efficiency of any surface treatment. However, analogy with other surface treatment methods of metal with plastic materials which have a fairly high water vapour permeability, and experiments which the author carried out some years ago by replacing the water skins by hydrophobe materials, allow at least a reasonable hope that it will be possible to overcome this most important and critical of all difficulties.

Shaping Techniques

A number of methods of shaping glass fibre laminates are known, not all of which are suitable for production of equipment used in the chemical industry. The following techniques should be mentioned.

(1) Lay-up system, wet or dry, or with pre-treated mat or cloth, on female or male moulds.

(2) The low-pressure systems, which either uses a pressure or vacuum balloon, or a combination of the two, as well as the autoclave method.

(3) The already mentioned preform method with matched moulds, as well as the high-pressure methods.

Generally it can be said that the mechanical performance of materials made according to the various methods will be the better the higher the pressure is during manufacturing. The glass fibres will be brought into closer contact and a higher grade of filling and a smaller amount of resin will be obtained in the final job. Whilst this is highly desirable, the economics of the building of chemical plant are such as to forbid the use of expensive equipment, as hardly any job will be repeated often. The only exception may be pipes and storage tanks in the oil industry and, possibly, some stock sizes of tanks for electro-plating. The fabricator or designer who caters for the chemical engineering field

will therefore have to resign himself generally to the application of a method which involves the use of a greater quantity of material than might otherwise be necessary. He will still find that in spite of this and on account of the small amount of depreciation on capital equipment, he will be able to produce quite economical articles.

Demands on Materials for Chemical Construction

To make a material suitable for construction in the chemical industry, it will have to fulfil, as mentioned in the introduction, a considerable number of requirements. (1) To begin with, it will have to have excellent chemical resistance, if possible even at elevated temperatures. In fact, the higher the upper temperature limit, the larger will be its sphere of application. (2) Further, many materials, especially metals, will resist perfectly a certain given reagent; small impurities, however, may upset this resistance and speedy failure may occur. Therefore it is demanded that, if at all possible, materials of construction should be free from sensitivity to any impurities which may be encountered. (3) The mechanical performance of a material must be adequate for the purpose in hand, and (4) it must either be available in the form of sheet, blocks, foil, rods and tubes, or it must be capable of being given these various shapes. (5) A material must lend itself to machining with more or less conventional equipment and tools. (6) It should be also of such a nature that accepted engineering practice can be used, and that no particularly difficult and special method need be applied for giving it the necessary shape.

Glass fibre laminates within limits fulfil all the above conditions. Two of the most important ones, strength and chemical resistance, are to a very high degree capable of variation and modification. The material can often be adapted to its purpose. Of course, economic considerations and mechanical and chemical resistance are very often contradictory factors for a special application, and each job may set problems which can only be solved by proper balancing of the possibility of fulfilling the various demands.

Strength of Laminated Plastics

The strength obtainable from glass fibre laminates depends on many factors. A very important one is the resin used for bonding and the degree of its adhesion to the glass fibres. This, as mentioned before, is dependent on the surface treatment which the glass fibres have undergone, and is the greater the smaller the shrinkage of the setting resin. Further, it has been recognised that the result will be the better the higher the glass fibre content and the lower the resin content. The following table will illustrate this :—

Table I—*Effect of Curing Pressures on Properties of Epoxide/Glass Cloth Laminate*

Curing pressure, pounds per square inch.	3	25	200
Resin, per cent	34	32	21
Ultimate cross breaking strength, pounds per square inch.	38,000	63,000	78,000

It is often economically essential to replace part of the glass fibres with granular fillers. This will detract, to a certain extent, from the tensile strength of the final laminate, but it will at the same time increase its impact strength very considerably. It will therefore be the first problem of the designer to choose a proper base composition which will give the final material the necessary strength which the article requires and the treatment it is expected to undergo during its life.

The second problem which the designer of glass fibre reinforced objects will have to consider is the type and positioning of the reinforcement. The more he is prepared to learn from the reinforced concrete designer, the easier his job will be. A number of observations which have been made when comparing the strength of glass fibre laminates made in different manners prove the correctness of this analogy. This means that the glass fibre must be lying as near as possible in the direction in which the stress is expected. This, of course, also requires that the glass fibre bundle should make as few undulations around the stress vector as possible. This indicates that plain weave should, as far as possible, be replaced by long shaft satin weaves, unidirectional weaves or even rovings. It also shows that, if at all possible, woven rovings should be used more than ordinary glass cloth, where the individual bundles are twisted. If the individual bundles are straight and coincide with the direction of stress, they will on application of load, be able to accept their share at once and fully. In woven cloth, where the crossing fibre bundles pass over and under each other, they will partly be stressed in shear. Before they are able to accept a load in the sense for which they are best suited, namely, tensile stress, they will try to displace by shear stresses the resin which is held between the bundles. Laminates from mats with glass strands lying in random directions are for this reason considerably weaker, weight for weight, than laminates made with glass cloth.

Thirdly, the designer who desires strength will have to choose a resin which shows as little shrinkage as possible. Resin with a high rate of shrinkage will tend to take the glass cloth with it on setting, and the undulations as described above will tend to be intensified with the consequence that the glass fibres will be able to take even less load than before. Whilst the tensile strength of non-reinforced polyester and epoxide resin is very similar, the mechanical strength of laminate made with these two resins is very different. The epoxide resin laminates are undoubtedly much superior to the polyester laminates, as their shrinkage is only in the neighbourhood of 2 per cent or even less, compared with the 5 per cent to 8 per cent of polyester resins. The excellent adhesion of the epoxide resins, of course, will be a contributory factor. If this theory is followed to its logical conclusion then it is obvious that laminates can be obtained which with the minimum of material will have the maximum of mechanical strength.

The designer will also have to consider very carefully the thickness of the individual fibre bundles which he will tolerate in his laminate. It has been stated that the tensile strength of laminates made with thin fibre bundles is greater than that of laminates made with thick fibre bundles, but that the impact strength moves in the opposite direction. It is also a well-known fact that the wet strength of thick fibre bundles is smaller than that of dry bundles and that again this difference is not so great for thin bundles as for thick ones. The reason for this is fairly simple. The maximum elongation of a glass fibre on stress is approximately 2 per cent before breaking. If two glass fibres are lying side by side, the one taut and the other one slack, and if a tensile load is applied on them, the taut one will break before the slack one has been able to take part or any of the applied load. If these two fibres are bonded together with resin, some part, but still not the whole length, of the slack fibre will be able to take part of the load and again the taut fibre will break before the other one. If we have a whole bundle of fibres this difference will be the more accentuated the more fibres there are in a bundle. It is always easier to arrange a few fibres carefully parallel and under nearly identical conditions than a thick bundle. For this reason the thick bundle will show a lesser tensile strength than the thin bundle. The same effect will also be noted when comparing wet and dry strength, as fibre bundles which are bonded with resin or even size will show very much less of the individualistic behaviour of a fibre than a wet bundle. There each fibre can easily slide along the other one, and the tauter ones will break before the slacker ones have taken any substantial part of the load.

Table II—*Chemical Resistance*

Chemical	Furane	Polyester	Epoxide	P.V.C.
Acetic acid	G.	F.	N.R.	G.
Acetone	G.	N.R.	N.R.	N.R.
Aliphatic hydrocarbons	E.	E.	E.	E.
Aluminium fluoride ...	E.	—	—	E.
Aluminium sulphate ...	E.	E.	E.	E.
Ammonium hydroxide...	E.	N.R.	E.	E.
Ammonium nitrate ...	E.	E.	E.	E.
Aniline	G.	N.R.	N.R.	N.R.
Aniline hydrochloride ...	E.	—	—	N.R.
Benzene	E.	F.	E.	N.R.
Benzene sulphonic acid...	E.	E.	—	—
Benzoic acid	E.	E.	E.	E.
Butyl alcohol	E.	E.	E.	G.
Butyric acid	E.	G.	F.	E.
Calcium chloride	E.	E.	E.	E.
Carbon bisulphide ...	E.	N.R.	—	N.R.
Chlorobenzene	E.	F.	—	N.R.
Chloroform	E.	N.R.	E.	N.R.
Chlorine	G.	E.	N.R.	Depends on conditions F or G.
Chromic acid	Cold dil. soins.	G. (cold dil. soins.)	N.R.	E.
Citric acid	E.	E.	E.	E.
Copper chloride	E.	E.	E.	E.
Copper sulphate	E.	E.	E.	E.
Ether	E.	—	—	N.R.
Ethyl acetate	E.	N.R.	N.R.	N.R.
Ethyl alcohol	E.	E.	E.	E.
Ethylene dichloride ...	E.	F.	F.	N.R.
Ferric chloride	E.	E.	E.	E.
Formaldehyde	E.	G.	N.R.	G.
Formic acid	G.	N.R.	—	G.
Hydrobromic acid... ...	G.	E.	E.	F.
Hydrochloric acid... ...	E.	E.	E.	E.
Hydrogen sulphide ...	E.	E.	E.	E.
Kerosene...	E.	E.	—	E.
Lactic acid	E.	E.	—	E.
Lime	E.	N.R.	E.	E.
Maleic acid	E.	E.	—	E.
Methyl acetate	E.	N.R.	N.R.	N.R.
Methyl ethyl ketone ...	E.	N.R.	N.R.	N.R.
Nickel chloride	E.	E.	E.	E.
Nickel sulphate	E.	E.	E.	E.
Nitrobenzene...	E.	N.R.	—	—
Nitric acid	N.R.	G. (cold) dil. soins.)	N.R.	E.
Oleic	E.	E.	E.	E.
Oxalic	E.	E.	—	E.
Phenol	E.	N.R.	N.R.	N.R.
Phosphoric acid	E.	E. (up to 50%) G. (up to 85%)	—	E.
Phthalic acid	E.	—	—	N.R.
Potassium chloride ...	E.	E.	E.	E.
Potassium hydroxide ...	E.	N.R.	E.	E.
Pyridine	F.	—	—	—
Sodium bichromate ...	E.	—	—	E.
Sodium bisulphite... ...	E.	E.	E.	E.
Sodium carbonate... ...	E.	F.	E.	E.
Sodium hydroxide... ...	E.	N.R.	E.	E.
Sodium sulphate	E.	E.	E.	E.
Sulphuric acid	E. (up to 70%)	E. (up to 50%)	E. (up to 50%)	E. (any concentration)
Toluene	E.	E.	E.	N.R.
Trichloroethylene	E.	F.	—	N.R.
Water	E.	E.	E.	E.
Xylene	E.	E.	E.	N.R.
Zinc chloride	E.	E.	E.	E.

Abbreviations used in chemical resistance ratings :
E.—Excellent (inert to the chemical).
G.—Good (slight discoloration or extremely slow attack).
F.—Fair (slow disintegration and may require minor annual repairs).
N.R.—Not recommended (attack too severe).

Chemical Resistance

Table II gives the chemical resistance of the two most frequently used laminating resins, polyester resin and epoxide resin. (As a typical example, "Duron 21" and "Duron 90," have been chosen.) To compare these

results and data, two columns have been added, one describing a standard grade of furane resin and the other rigid P.V.C. At the first glance this list is very promising indeed. It must, however, not be forgotten that all experiments were made at ambient temperature. The resistance of P.V.C., as mentioned, will remain unchanged at least up to 40 deg., if not 60 deg. Cent., and of the furane resin, in most cases, to 150 deg. to 180 deg. Cent. Also, whilst both polyester resins and epoxide resins give good performance over a short period of time, after a few months frequently a fairly rapid deterioration starts which detracts much of the value of the resin for chemical engineering projects where a very much longer life is required.

(To be continued)

Spare Parts and Convertibility

(CONTRIBUTED)

STRIPPED of the economists' jargon, convertibility, for this country, means the ability of British exports to compete with American on level terms. Our hesitation in taking the plunge is largely due to doubts whether they can do so, at any rate as far as the substantial sector of our trade comprised of engineering plant and equipment is concerned. In what respect are we failing ? Not in the quality of our products, nor in the prices or deliveries we offer. Our salesmanship is keen and energetic and in design we lead the world. The answer will be found in any typical report from a British trade commissioner or commercial councillor : " British equipment is popular in this market, but suffers from lack of after-sales service." With certain honourable exceptions, notably the motor manufacturers, the indictment is all too true. Far too many British engineering firms still take the traditional view that their function is confined to the making and delivery of the product to the user. They completely ignore the fact that it is the performance of the machine during its life in the hands of the user on which they will be judged, and on which their future orders will depend. They argue that this is the province of the local agent or distributor, that it is his function to give service to customers and look after the good name of the machine once it has been delivered. Theoretically this is sound enough, but in practice the manufacturer will find himself compelled to shoulder a considerable portion of the service responsibility, if he wishes to maintain his reputation. Much of the machinery and equipment that has flooded out from Britain since the war, has gone to countries where reputable distributors are scarce or non-existent. The " know-how " and will to operate and maintain machines have to be imported, just as much as the machines themselves.

This is a world problem and one of growing dimensions. With the rapid growth of industrialisation, and productive capacity increasing by leaps and bounds, it is no longer production that is wanted, so much as organised maintenance of machines already in being. One has only to take a brief tour overseas to find machinery lying unused, waiting for an essential spare part, or prematurely ruined by abuse. In some countries, there is even reversion to manual methods, simply for lack of a guiding hand to help keep plant in operation. A vital factor in this maintenance problem is the organised provision of adequate spare parts. How many British manufacturers have a spare parts department keyed up to provide any conceivable spare " off the shelf " not only from their own spares store, but from the shelves of their distributor in every country in which they have sold machines ? For it is little consolation to the user, six weeks away by mail boat, if the part is in stock in England. He wants to walk into the depot in, say, Rhodesia and find it waiting for him. Too many British firms regard the production of spares as a necessary evil, an interruption to production " runs," only to be undertaken when short of other work. A junior clerk is detailed to " look after spares," and spends his time writing letters of apology, indicating as best he can to irate customers that " everything possible is being done to expedite production of the part required." Simple arithmetic will show that with a constant output of new machines, assuming an average operational life of ten years, there will be at any time 120 in service for every one produced per month. And although spares usage varies with different products, the maintenance of these 120 machines in service will inevitably result in a heavy spares requirement, which should have first claim on the capacity of the factory.

No one denies that with the increasing complexity of modern machines, and the frequent introduction of new models, the systematic provision of spares is an extremely complex matter. No matter how carefully prototype testing is carried out, and initial scaling of spares prepared, certain parts always break or wear out sooner than anticipated, calling for rapid reassessment of spares requirements, and a constant vigilant examination of usage figures. Then there is the vexed question of spare parts books, without which users and distributors overseas have great difficulty in ordering their requirements. Making these books available, and keeping them up to date to match the progress of design, modifications and improvements, is a considerable administrative task.

What is needed is a complete change of heart, and a recognition that the supply of spares and service " know-how " for the machines that have been delivered by any manufacturer, should be the first charge on his future productive capacity. Time limits must, of course, be set for each kind of machine, beyond which further repair is uneconomic, but within these limits the ready availability of parts should be regarded as a moral commitment. To achieve this standard (which is common practice among our American competitors) there must be carefully organised spare parts and service departments, with managers of sufficient status to ensure that the spares and service point of view is kept before higher management, so that the spares requirement is adequately met by production. Furthermore, the spares and service departments must be so organised that they can take an active interest and exert their influence not only in the spares arrangements at the factory, but also in the spares depots and service arrangements of the firm's distributors throughout the world. A machine in operation, wherever it may be, is a better advertisement for its maker than any glossy publicity, and money spent on really effective spares service will bring an infinitely greater return than the inflated advertising budgets, on which so many manufacturers place their hopes.

There is another aspect of this spares and service problem which has considerable influence on British trade overseas. In the past Britain was by far the largest investor in overseas countries, and as a result railways, oilfields, mining companies, public utilities and other pioneering developments have been built up, with their policy, including purchasing, controlled or strongly influenced by a head office in London. Since the war, and with the current pace of political development, there has been considerable devolution of control, but even to-day, in our Colonies and elsewhere, the man on the spot frequently has less say in the equipment to be purchased than has his buying office in London. Naturally, this is extremely convenient for British exporters, but it carries an inherent danger in that it tends to perpetuate the ignoring of servicing problems, since, however dissatisfied the user in the field may be, orders can still be obtained on the " old boy " basis, by keeping the London buyer happy. Meantime the Americans, taking a more practical view of machinery operation, and recognising that only by service on the spot can they maintain and build up their trade in British spheres of influence, have gone to great lengths to find active distributors, help them to organise spares and service facilities, and to insist on their giving first-class service to users.

It is a standard excuse of British manufacturers that the Americans moved in on their markets while they were busy with the war, but if the truth be told it is because the Americans recognised and met the service commitment while we continued to rely on selling in London, that American products are to-day so popular in many British territories. British makers who are now at last waking up to their responsibilities towards their own plant overseas, and are trying tentatively to establish service facilities comparable to the Americans, have only themselves to blame when they find all the well-established distributors preoccupied with American franchises. They must recognise that there is only one course open to them—to do as the Americans did, find or create a distributor and steadily build him up in close co-operation, until he can meet the service and spares needs of their joint customers, in such a way that British plant can match American, not only in design and workmanship, but also in the service given in the field.

In this age of mechanisation, the provision of a world servicing network for their products is one of the biggest challenges facing British engineering exporters to-day.

High-Speed Laboratory Mill

A LABORATORY mill stated to grind many times faster than ball mills of orthodox design is being put on the market by Steele and Cowlishaw, Ltd., Cooper Street, Hanley, Staffs. It consists of a floor-mounted casing of 2ft diameter by 4ft 6in high, containing four hard porcelain pots, each having a grinding capacity of 2½ pints. A larger version equipped with four 5-gallon pots is also available. These pots are removable and interchangeable, so that standing time of the machine is reduced to the time required for the change-over, no cleaning between runs being necessary. This equipment is intended for grinding and dispensing paints, milling powders and pastes for cosmetics, grinding ceramic frits, and similar applications. In the case of the grinding of granulated metal to powder, the firm quotes tests in which, after half an hour's grinding, 80 per cent of the powder passed a 300 mesh sieve.

Melting Shop with a 60-ton Electric Arc Furnace

A new melting shop which has recently been placed in service at the Stocksbridge Works of Samuel Fox and Co., Ltd., has a 60-ton electric arc smelting furnace. With its weekly potential output of 1200 ingot tons this furnace will double the works' output of high-quality steels.

THE productive capacity for alloy and special steels has been considerably increased at the Stocksbridge Works of Samuel Fox and Co., Ltd., by the construction of a new melting shop equipped with a 60-ton arc furnace. This furnace is stated to be the largest of its kind in this country and with its potential output of some 1200 ingot tons a week it will double the electric melting capacity of the works for high-quality steels. With the commissioning of the new installation it is expected that the existing high-frequency and small arc furnaces of the firm will be increasingly devoted to the melting of stainless, heat-resisting and other highly alloyed steels. The new furnace will primarily be concerned with the production of steels with a relatively low alloy content. Most of this output will be supplied as semi-finished steel to the rerolling, drop stamping and tube-making industries, although some of it will be processed in the works' special wire and strip departments.

When the decision was made to build the new melting shop at the west end of Stocksbridge works it was also planned, with a view to future developments, to reconstruct and extend the adjoining raw material yards so that they would serve both the new and the old shops. For the complete project a level site of some 100,000 square feet was required, and to obtain this area a major earth-moving problem arose. The works is situated on one side of a long narrow valley and to make the extensions possible it was necessary to cut into the adjoining hillside and excavate some 750,000 tons of soil. This soil was carted by lorries to the opposite side of the valley where it has been built up to provide a series of level playing fields for Stocksbridge. To provide access to the new electric melting shop it has also been necessary to build a pre-stressed concrete bridge across the River Little Don and lay down more than 3 miles of new railway track.

The reconstructed stockyard is about 1000ft long and two gantries, each 90ft span, serve its full length. A 5-ton overhead electric travelling crane on each gantry is fitted with a limited swing magnet for handling the raw materials. Sufficient space is available in the yard to accommodate fifty different varieties of scrap steel and pig iron, and it is eventually to be fitted with a system of movable walls for material segregation purposes. At one end of the yard is a two-storey structure, the main lower floor of which forms an alloy store, 50ft wide by 222ft long. Bays are arranged in this store for accommodating more than twenty kinds of the alloys required for the manufacture of special steels.

The alloying materials are delivered to the stores in sacks and barrels and provision is made for batching them for delivery as required to the melting shop. At one end of this store the batches of materials are dried in ovens, crushed, weighed and packed and sealed in large steel canisters in which they are transported to the melting shops ready for immediate use. The flat roof of the store forms a reinforced platform on to which the stockyard crane rails are extended. This platform is roofed and walled on three sides to provide a convenient elevated servicing station for the overhead cranes serving the stockyard. An amenities block adjoining the stores provides a mess room, a wash room, a changing room, &c., for the yard staff.

The new melting shop consists of three bays, one 366ft long by 70ft wide and two 240ft long by 60ft wide. It is a steel-framed building with a monitor roof making extensive use of castellated beams. The crane girders and columns of fabricated plates are spaced at 48ft centres and are designed to provide ready communications at high level with protected walkways passing through the web of the stanchions. The high/low flat roof has extensive glazing to provide the best possible natural lighting conditions in the building. A large capacity dust-extraction plant maintains good working conditions by quickly removing polluted air from the vicinity of the furnace and casting pits when they are in operation.

Raw materials are delivered by rail to one side of the building, where they are unloaded by a 10-ton overhead crane into two long timber-lined bunkers. Between these bunkers is a platform carrying a 60-ton capacity transfer car and weighbridge. The raw materials are loaded by the overhead crane into a large charging basket which is set on the transfer car. When the basket has the required charge the transfer car is drawn off the weighbridge and out into the adjoining charging bay, which is served by an 80-ton overhead crane.

The charging basket is of bottom opening construction and it has four large brackets or feet, spaced round its circumference. These brackets support the basket on the transfer car during the loading operation and on the shell rim of the furnace during discharging. A large pin painted red is welded to the extremity of each bracket, and these pins register in tapered sockets round the furnace top when the basket is being lowered. As the pins and their brackets on one side of the furnace can be clearly seen by the crane driver they serve to speed and simplify the charging operation. When the basket is in the unloading position on the furnace, as shown in Fig. 1, the bottom doors are opened by the drawing in of the locking gear chain with the crane auxiliary hoist.

The 60-ton arc furnace is situated in the centre of the shop between the charging bay and the casting bay. The chutes of the flux material storage hoppers are situated in the partition of the raw materials bay immediately opposite to the furnace. The alloying and slag-making materials are charged into the furnace by a mobile diesel engine-driven charging machine. From a control room adjoining the furnace the operator at the control desk has a clear, unobstructed view of the charging side. At the back of the control room there is a special wall rig for assembling and storing the carbons for the furnace.

60-Ton Arc Furnace

The new 60-ton arc melting furnace was made by Birlec, Ltd., Erdington, Birmingham, under licence from the Pittsburgh Lectromelt Furnace Corporation. Its design is based on current American practice for large furnaces. It is a top-charged, direct-arc, tilting "Lectromelt" furnace equipped with three automatically adjusted, vertical carbon electrodes; each electrode is 20in in diameter, 6ft long and, with its supporting arm, weighs 20,000 lb. The electrodes are supplied with power from the mains via a 15,000kVA transformer which is described below. High-conductivity copper castings are used for the electrode clamps which are water cooled. Slipping and tightening of the electrodes in these clamps is effected by a pneumatically-operated opening, and spring-closing, mechanism.

The furnace shell is cylindrical with an inside diameter of 19ft, backed with an 18in thick refractory lining. The bottom refractory lining is 27in thick and that of the roof, which is suspended at four points, is 14in thick. All the refractory lining was carried out by the Oughtibridge Silica Firebrick Company, Ltd., and Steetly Doloma Processing, Ltd., and brief details of the refractories are tabulated herewith:

Sub-hearth brickwork ...	Stabilised dolomite bricks
Side walls	"Britmag" magnesite tubes, supported on "Britmag" magnesite bricks
Roof	Oughtibridge standard silica
Hearth and taphole	Rammed tarred doloma to cover the starting-up period, to be followed by graphitised dolomite when the furnace goes into regular production. "Doloset" cement lined taphole

Three views of the furnace are reproduced herewith. For charging the furnace the roof is lifted and swung clear towards the launder by a hydraulic ram. Hydraulic rams also provide tilting movements of the furnace, up to 45 deg. forward (Fig. 4) and 15 deg. backward. The hydraulic equipment consists of three 30 h.p. motor-driven oil pumps which are installed in the basement and are controlled by

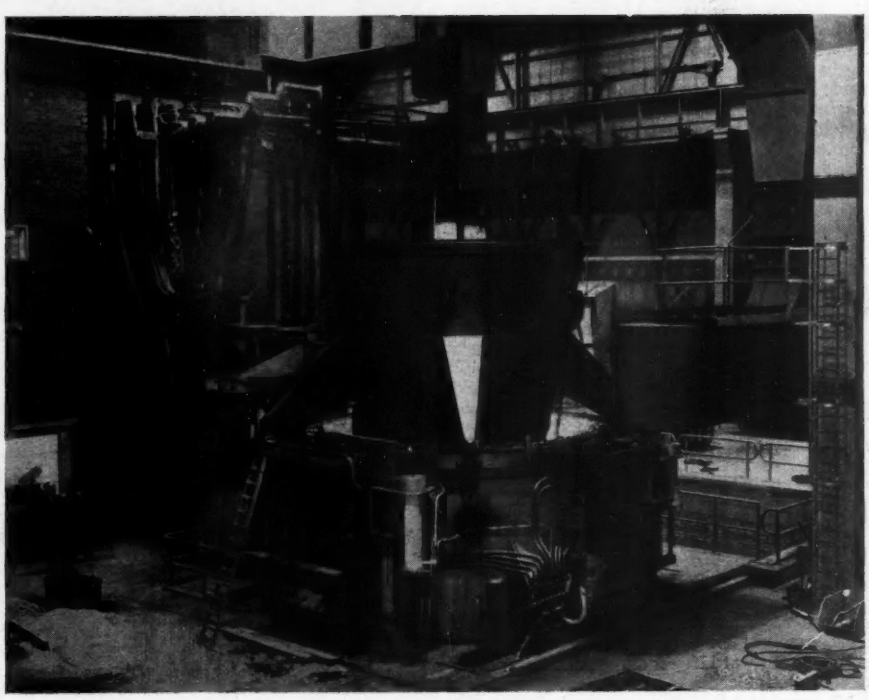


Fig. 1—Charging basket in discharge position on furnace with the locating pins on the feet registering in the furnace sockets

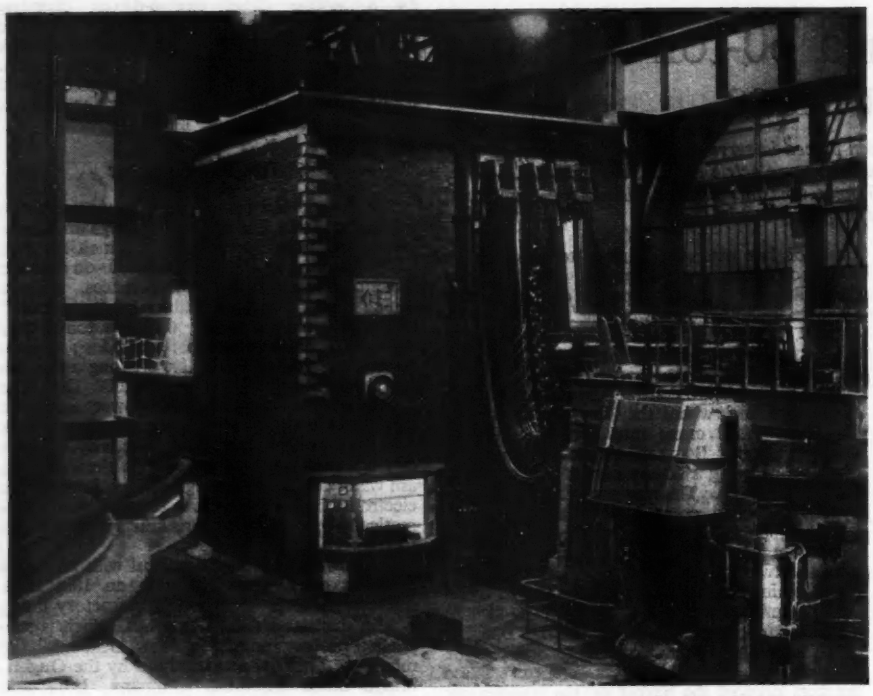


Fig. 2—60-ton electric furnace. The control cabin can be seen, and, above it, the illuminated dial indicator for the melt temperature

push-buttons and electro-hydraulic operating valves.

The compressed air operated slagging door and the side doors, together with their arches and jambs, are water cooled, as is the top of the furnace shell ; the rim of this shell is in the form of a continuous bezel ring of box section to act as a stiffener and to locate the roof ring.

When the furnace was ordered the possibilities of electromagnetic stirring were under consideration and the plant layout was arranged so that modification could be effected, if required. In the belief that such a change will improve the quality of the steel-making process, the company has decided to fit the furnace, next year, with an electro-magnetic stirrer of Swedish design.

Electrode Control

Each of the three electrodes is controlled by an electrically-driven winch mounted on the side of the furnace. The drive is applied to the electrode by a wire cable which is passed over pulleys to give a 4 : 1 advantage and is then taken to the winch drum which is coupled to a B.T.H. 15 h.p., 725 r.p.m., " MDX " mill motor through a 198 : 1 double worm reduction gearbox.

Control of the power input to the furnace is achieved, in the usual way, by adjusting the position of the electrodes to maintain constant arc impedance. The winch motor operates in response to the arc voltage and current, causing the electrode to follow the metal as it melts. This result is achieved, as described more fully below, by B.T.H. equipment, consisting of an amplidyne-controlled generator supplying each winch motor.

In addition to this automatic control, hand control is also provided by appropriate switches. The electrode speed on automatic operation is nominally 6ft per minute ; actually it is proportional to the distance the electrode has to travel to attain correct arc-impedance so that the effect of inertia is minimised. Before the arc has struck, the downward speed is limited to an arbitrary value to minimise the possibility of electrode breakage. On hand control, speeds for raising and lowering the individual electrodes are initially set at 6ft per minute and 4ft per minute, respectively. There is an additional master control set to raise the three electrodes simultaneously at 12ft per minute and lower them at 6ft per minute.

As the electrodes are not counterbalanced, the weight is compensated for electrically, as explained below, in such a way that the winch motors exert a constant lifting force on the electrodes. This constant force is superimposed on the automatic signal at all times so that there is no tendency for an electrode to run down and dip in the bath—an important provision when low carbon steels are being made. A brake is mounted on the motor shaft to prevent the weight of the electrode system turning the motor when the equipment is not energised.

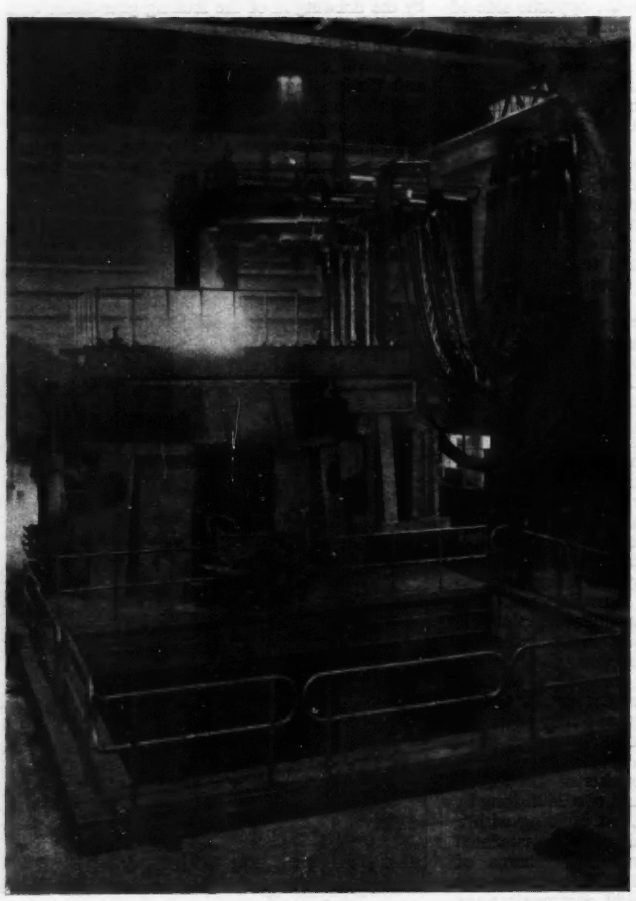


Fig. 3—The furnace with the electrodes partly withdrawn. The pouring pit is in the foreground

There are four m.g. sets (one for each electrode, and a spare), each consisting of a 13kW generator, an amplidyne and a 25 h.p. driving motor. The generator is specially designed for commutating high peak currents and its field is arranged so that it can be forced by the amplidyne. Each winch motor is supplied by one of these m.g. sets working on the Ward-Leonard system, with the amplidyne controlling the generator field.

The control circuits for each electrode are mounted on a detachable self-contained panel which, in turn, is mounted in the control cubicle, enabling any electrode panel to be removed for servicing and replaced by a spare panel with the minimum of lost time. There is also a supply panel for starting the m.g. sets and other auxiliary circuits, and a change-over panel which allows the operator to select any three of the four m.g. sets as required.

Each electrode control panel has the standard circuits for comparing the arc voltage and arc current. A simplified diagram of the control scheme is reproduced in Fig. 5. The arc voltage is applied across points 15 and 19 through resistor *R*9 (which compensates for tap changing) to rectifier *W*4 ; hence a d.c. voltage proportional to the arc voltage appears across resistors *R*6 and *R*11. Similarly, a measure of the arc current, as determined by the current transformer, is applied to a saturating-core current transformer *TR*2 (which automatically limits peaks) and, after rectification by the rectifier *W*5, it produces a corresponding d.c. voltage across the resistor *R*7. Thus two d.c. voltages are compared and the difference is passed through the control field of the amplidyne, *X*1*X*2.

There are a number of other components on this panel to provide various characteristics. For example, the speed of movement of the electrodes before the arc has struck is adjustable to a lower value than when under normal operating conditions, so that it cannot strike the charge at high speed and break the electrode. Relay *CR*1 operates when current is flowing in the electrode and changes over from slow, or pre-strike electrode speed, to normal operating speed. The pre-strike speed is adjusted by means of *R*8. There is also a potentiometer (*R*6) on the operator's control panel which allows him to adjust the electrode current without tap changing on the current transformer. Thus the d.c. voltage across *R*7 is compared with all or part of the voltage across *R*6 and *R*11, so that the electrode current is adjusted by changing the potentiometer adjustment.

Other circuits of interest are the differential field circuit, which provides speed forcing and reduction of residual voltage (resistor *R*4 and amplidyne field *X*4*X*6), and the stabilising circuit which prevents hunting (condenser *C*2, resistor *R*3 and stabilising field *X*7*X*8). There is also a bias circuit which electrically compensates for the weight of the electrodes ; a separate source of voltage is provided (via transformer *TR*4 and rectifier *W*8) to potentiometer *R*15 and some of this voltage is injected in the circuit of the control field *X*1*X*2 of the

amplidyne so that the generator circulates sufficient current to produce a torque on the winch motor and support the weight of the electrode.

Any three of the four m.g. sets may be selected to drive the three winch motors by means of multiple change-over switches with interlocks which change over all main and control wiring. In the unlikely event of trouble on an m.g. set during a melt, a change-over can be quickly made to the spare set with hardly any interference to the continuity of the process.

The incoming supply is fed to the supply panel and then through an isolator and h.r.c. fuses to the starters and control circuits. The three selected m.g. sets are started from a common contactor but have individual overload relays. A starter is also provided for testing the spare m.g. set while the others are running. A transformer and rectifier supply the shunt fields of the winch motors.

The electrode regulator and other control equipment is operated from a control desk located in a small room near the furnace, as shown in the photograph reproduced in Fig. 2. There are individual electrode control switches and a master or group electrode control switch for manual control of the electrodes and a "Hand-Auto" selector switch so that the operator can choose the method of working. Normally on starting up, the circuit-breaker is closed and the selector switch put in the "Auto" position so that the electrodes come down, strike the arc, and continue to operate at the pre-set current without further attention. Because of the size and importance of continuity of operation all important components were duplicated in such a way that the change over could be effected quickly. We learn that when this equipment was put into service, early in November, it was noted that the power input to the furnace was unusually constant. In the early stage of the melt, when control is most critical, power fluctuations were of the order of only ±10 per cent and after ten minutes they were further reduced. Over a number of melts the arc was not extinguished after the initial strike until the "cave-in" period occurred.

Electrical Supplies

Electrical power for the new plant is supplied by the Yorkshire Electricity Board through a ring main system into the melting shop substation. The auxiliary services operate from a 440V, three-phase, 50 c/s, four-wire supply.

The supply for the arc furnace is distributed at 11kV through a six-panel metalclad switchboard made by the English Electric Company, Ltd. It comprises an incoming single-busbar circuit-breaker, four duplicate-busbar units with oil-immersed selector switches for distribution, and a single-busbar unit for the arc furnace supply. Hand-charged spring operation is used except for the circuit-breaker controlling the arc furnace, which is solenoid operated for local or remote control, the solenoid being energised from a 220V d.c. supply. The circuit-breakers are oil-filled horizontal draw-out equipments having hand racking devices with reversible ratchets.

For the metering and protection services associated with the arc melting furnace, six 1000/5A current transformers are located in a separate oil-filled chamber on the fixed portion of the arc-furnace circuit-breaker unit. An 11,000/110V, three-phase, star/star, 200VA voltage transformer is housed in a withdrawable steel tank and immersed in oil, together with h.r.c. fuses; the tank is positively earthed and locked in position when in circuit. There is a shunt trip coil, operated from a 30V battery supply. Operation of any of the following protective circuits will trip the circuit-breaker: thermal over-current protection; instantaneous over-current protection; 11kV winding earth fault protection; 22kV winding earth fault protection, and time-delayed under-voltage protection. All relays and control equipment are mounted on the English Electric control cubicle.

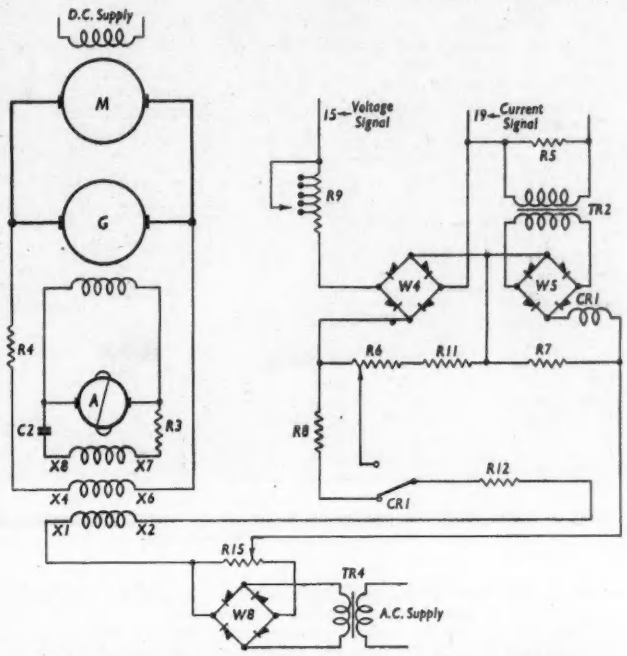


Fig 5—Simplified control scheme for 60-ton arc furnace regulator

Furnace Transformer

The transformer supplying the furnace is the largest of its kind installed in this country and is the first to be provided with on-load voltage control. It is an English Electric transformer designed to give a maximum output of 15,000kVA from an 11kV, three-phase, 50 c/s supply, and the secondary voltage can be varied between 325V and 90V by a three-phase, motor-operated tap-changer. Operation of the tap-changer is controlled by a multi-point selector switch mounted on the furnace operator's control panel. Any desired voltage can be pre-selected and whereupon the tap change takes place automatically. There is a remote tap-position indicator on the control panel which gives an indication of the tapping in use at any moment.

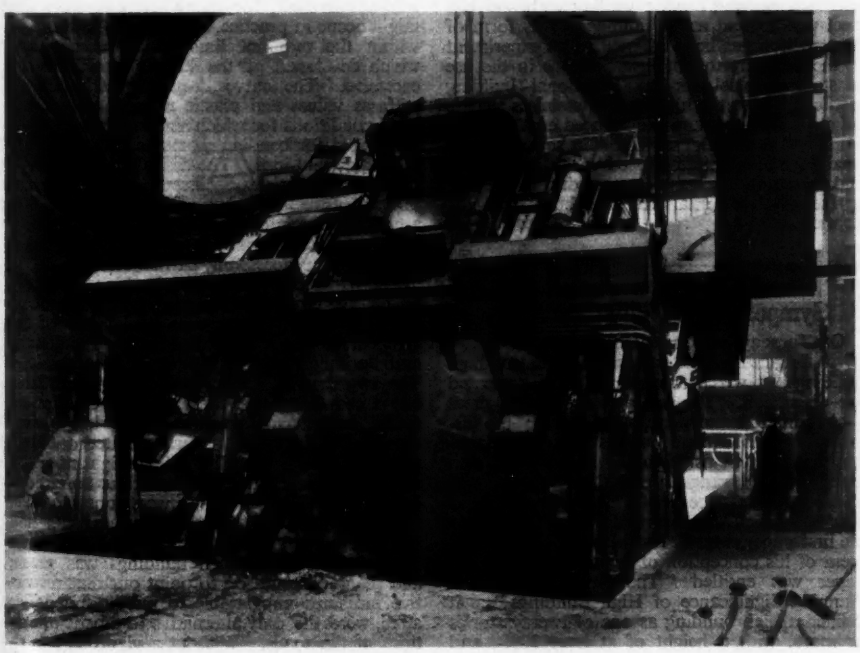


Fig. 4—The furnace tilted at the completion of its pour. The furnace bottom is of stainless steel and an electromagnetic stirrer is to be fitted

The transformer is arranged as two units housed in a common tank and consists of the furnace transformer proper and a tapped regulating unit. The furnace transformer is of double-wound construction with a fixed turns ratio, and the secondary windings consist of a large number of disc coils in parallel to carry the very heavy output current of 29,000A. The disc coils are paralleled on rectangular-section copper bars which pass up through the oil conservator to form the output terminals. To reduce the winding current an externally-made delta connection is used. The regulating unit is a delta/star, double-wound transformer connected to the primary windings of the furnace transformer via the on-load tap-changer. Because of the wide voltage range covered, the secondary windings are wound as multi-layer coils, each layer forming one tapping step. Flexible cables connected to the layer ends are led through Bakelised-paper tubes to the top of the transformer and thence to the selector switch of the tap-changer.

On-load tap-changing by the reactance-bridging method is used, the associated mid-point auto-transformer being located in a pocket on the tank side. The on-load tap-changer, mounted on the floor of this pocket, is built as a complete unit consisting of the selector switch, with the diverter contactors mounted below it, and a motor driving mechanism, which is contained in a cabinet at the right-hand end of the selector switch chamber. Because of the onerous duty imposed on the diverter contactors by the frequency of operations, a special alloy is used for the contact tips, and the contactors are housed in separate, oil-filled, drop-down tanks for ease of maintenance.

Cooling arrangements for the transformer consist of two 100 per cent capacity oil/water heat exchangers. Normally only one cooler is in use at any one time, to enable cleaning and maintenance to be carried out at regular intervals without disturbing the operation of the equipment. Two oil pumps are provided, and the pipework and valves are so arranged that either pump may be used with either cooler; the pump motor starters are interlocked to

Fig. 6—Melting shop with pouring pits on the left and teeming pits extending rearwards towards stripper and cooling pits.

prevent simultaneous running of both pumps.

Indicating and recording equipment is provided for measuring the incoming supply current, the power taken by the furnace, and the power used per heat. There are similar facilities for roof and hearth temperature measurement and equipment is installed for indicating flow and temperature on the various water cooling circuits.

Temperature measurement of the molten metal is made by a Schofield platinum/platinum-rhodium thermocouple, which is connected by flexible cable to a 20in diameter indicator, with an illuminated dial, mounted on the control room wall, as can be seen in one of our illustrations. At the same time the temperature is automatically recorded on a paper chart in the control room.

Operational safety is ensured, where desirable, by interlocks. For instance, operation of the transformer tap changing equipment when the circuit-breaker is closed is prevented by electrical interlocks. Similarly, tilting of the furnace, except when the roof is closed down on the shell, is prevented by mechanical and electrical interlocks.

As soon as the charge is fully melted in the furnace a sample is taken for analysis, after which iron ore and limestone are used to make an oxidising slag and thus promote a "boil," during the course of which phosphorus and carbon are reduced to the desired level. Once the required conditions are reached and confirmed by analysis the furnace is tilted and the phosphorus-rich oxidising slag is run off. After the slag is removed, the metal is deoxidised by adding ferro-silicon, and a further slag made up of lime, fluorspar and carbon is added. During this second period reducing conditions are maintained in the furnace and the sulphur content of the steels is thereby brought down to very low limits. Throughout the working period samples are taken and chemically analysed, and when the operator finds that the desired conditions have been reached the final alloying additions are made, the temperature of the bath is checked, and the steel is tapped out of the furnace.

The 366ft long bay in which the casting, stripping and cooling of the ingots is carried out is served by a 100-ton and two 15-ton overhead cranes. In this bay, one end of which can be seen in a photograph we reproduce in Fig. 6, the ingot casting pits immediately adjoin the furnace pouring pit. An ingot stripper and a weighing machine are situated between the casting pits and a group of cooling pits at one end of the building. After cooling the ingots are loaded for despatch on wagons on a rail track running along the full length of one side of the building.

All the control and operating gear for the furnace is arranged in chambers below the furnace. The electricity, gas and other services for the shop are brought in through a central service duct arranged laterally under the main buildings. To prevent excessive dust deposits in the control room, and to reduce air movements within the main building, clean air is introduced to the furnace position and control room through the underground service duct.

The administration building adjoining the new melting shop is of steel frame construction and its upper floor has been clad with a system of non-load bearing curtain walling with stainless steel panels used as an infilling. This form of construction has been adopted as an experiment by the company to obtain experience in the use of stainless steel for non-traditional building methods. In it the high cost of stainless steel is offset by lightness and the reduced cost of steelwork and foundations. The 40in square panels used as infilling were clipped easily in position and no scaffolding was necessary during building as the whole external wall was built from the floors.

Symposium on High Buildings

On Tuesday, December 7th, the Institution of Civil Engineers held a symposium on high buildings, at which four papers were presented for discussion. The meeting aroused a great deal of interest and was well-attended; the discussion included contributions from other professions, as well as from the Institution's own members, and ranged over the social as well as the technical aspects of the problems of town planning which were examined by the author of the first paper, Mr. S. Kadleigh, in the development of his conception of a high building. His paper was entitled "The Social and Town Planning Significance of High Buildings"; it defined a high building as one of twenty stories or more, with a height of at least 200ft, and went on to give an historical outline of the ideas and influences behind the development of town planning in this country over the past 150 years, which had been influenced, it was pointed out, by the "garden city" and the traditional "model town," so that tall buildings such as were found in many cities abroad were not favoured. The author contended that the century-old conception of a "model town" was dangerously out of date.

The resulting situation, apparent to-day in the process of "decanting overspills," was then considered; its effects were to upset the balance between town and countryside, it was stated, and the ominous tendency to prescribe mass migration of families away from the ties of their native districts. This was all generally considered to be inevitable, the paper went on, but the use of high buildings with the "multiple use of land" as put forward in the paper was in fact an alternative up-to-date method of reconstructing our congested cities. The paper gave an example of this alternative method of development as applied to a typical urban borough where there existed sites, which at present were not considered suitable for development, but which, nevertheless, could be developed to house complete communities of 8000 to 10,000 people, with amenities and benefits not normally considered possible in the centres of our cities. The basic idea was the provision of facilities for a community of that size, including, for instance, shops and open spaces, as well as homes and offices, in a single "high building."

The second paper of the symposium—"High Building Frames and Foundations," by Professor A. L. L. Baker—discussed elasto-plastic design in reinforced concrete. His paper dealt principally with a method, based on the ultimate-load theory, of determining the wind stresses in multi-storey Vierendeel frameworks of more than one bay. Other structural forms for resisting wind pressure were discussed, as were various elastic theories used for the analysis of building frames.

The design method proposed used simple formulæ and was a further development of a trial-and-adjustment procedure of design, using the plastic hinge theory described by the author in a paper he gave to the Institution in 1953. That method assumed a suitable disposition of plastic hinges. With the aid of tables, a trial-and-adjustment procedure was followed until members of the framework had their appropriate stiffness values, and plastic hinge sections their appropriate bending moment values.

The present paper extended that process to the special case of a four-bay framework any number of stories in height. It was shown that a set of curves could be prepared from which the maximum rotations of plastic hinges could be quickly determined, provided various stiffness ratios of the framework were within certain limits. It was shown that, for many frameworks which might occur in practice, stiffness ratios would lie within the required limits and the rotations which developed at the hinges would not be excessive. The curves, together with limiting stiffness values and plastic moment values, defined conditions for which simple formulæ could be applied for bending moments due to vertical load and wind load. The design of raft foundations was also briefly discussed. A typical layout of a raft frame was shown in the paper as was a typical tall reinforced concrete framed building in Johannesburg, where a number of tall buildings had been successfully carried on rafts.

The paper on foundations for high buildings, by Dr. Skempton, is reproduced in abstract on page 848 of this issue. The final paper of the symposium was "High Buildings—The Traffic and Parking Problems," by S. J. Chamberlain. The two crucial traffic problems of congested city areas—to ensure satisfactory circulation of traffic, and adequate space for parking—were discussed in this paper. It was pointed out that, although an isolated tall building might not itself create a major traffic problem, serious conditions arose if many high buildings were constructed in an area where few, if any, improvements had been made in the old street plan. An analysis of the traffic using such buildings was given, and the paper went on to point out that restrictive measures unpalatable to public and police alike, were the only alternative to drastic alterations of the roads. Without a vigorous contribution to parking space in central areas, it was contended, a partial or complete strangulation of traffic would take place.

Machinery at the Smithfield Show

No. III—(*Concluded from page* 809, *December* 10*th*)

THE Smithfield Show and Agricultural Machinery Exhibition, which was held at Earls Court, London, last week, ended on Friday evening. The attendance during the five days of the show was 65,914, and although this figure was below last year's total it has been stated that the number of overseas visitors was higher. There was, as usual, keen and critical interest shown in the numerous machinery and implement exhibits, which, as is now customary at the "Smithfield," occupied a far larger space than the excellent exhibition of livestock.

One of the special events arranged in connection with the exhibition was a meeting, in the Richmond Hall at Earls Court, of the Institution of British Agricultural Engineers. It was held on Thursday afternoon and attracted a large company of members and visitors to hear a paper presented by Mr. C. Culpin on "Ventilated Silos for Grain Drying and Storage." Some extracts from the paper are printed on page 859 of this issue. In our last two issues we have described briefly some of the newer machines and implements displayed at Earls Court. Here, we conclude those descriptions.

At this year's show there were to be seen many examples of the insecticide spraying equipment which fulfils an increasingly important role in mechanised agriculture at home and overseas. Several sprayers of different kinds were exhibited by the Dorman Sprayer Company, Ltd., 408, Cherry Hinton Road, Cambridge. A new machine recently produced by the firm is illustrated in Fig. 12. It has a tank capacity of 150 gallons and is arranged for operation by the Lanz "Alldog" tool carrier. The Lanz tool carrier, which was again shown by H. Leverton and Co., Ltd., Spalding, Lincs, was described in our issue of December 11, 1953. It has an overall length of about 12ft, a width of 7ft 2¼in, and weighs just over 1 ton. The power unit is a 14 h.p. single-cylinder diesel engine, with a maximum speed of 3000 r.p.m., and the "tool carrier" consists of a rectangular tubular frame, in front of the engine and transmission, upon which a variety of implements can be easily mounted. The normal equipment of the tool carrier includes two power take-off shafts, one at the front and the other at the back of the engine. The Dorman sprayer, which was shown mounted on the tool carrier, has a mild steel, welded, flat-topped tank. Its equipment includes a three-paddle agitator mounted on a horizontal shaft, which is belt driven from the forward power take-off, and a gear pump, constructed of bronze and stainless steel, with an output of 12 gallons a minute, which is chain driven from the rear power take-off shaft of the tool carrier. The spraying boom, which can be "folded" around the tank for transport, gives a working width of 30ft and is equipped with flat fan nozzles placed at 18in intervals. The spraying height of the boom is adjustable between 18in and 43in.

Another firm which exhibited a variety of spraying equipments is E. Allman and Co., Ltd., Birdham Road, Chichester. A recent addition to this firm's products is the "Genimec" low/medium volume sprayer. This sprayer is a tractor-mounted machine with a 40-gallon cylindrical galvanised tank. The "Rollervane" pump, which forms part of the equipment, is designed for working pressures up to 150 lb per square inch, and is directly attached to the tractor's power take-off shaft by a keyed sleeve and check chain. The spray boom is in three folding sections which together provide a working width of 18ft 2in, the height being adjustable between 18in and 38in. The sprayer is controlled by a single lever, the system incorporating a method of "suck-back" which prevents dripping from the nozzles when in the "off" position and while the pump is still running.

The combine harvesters shown at Earls Court included a modified version of the "Albion," which is manufactured by Harrison, McGregor and Guest, Ltd., Leigh, Lancashire. This machine (Fig. 13) has a cutting width of 4ft, and is arranged for operation by a tractor power take-off shaft running at a speed of 540 r.p.m. This harvester has a somewhat wider body than its predecessor, an alteration that has been made to give a straight-through flow of the crop from the cutter bar to the drum. The length of the header has also been increased to lessen the slope up which the crop is carried. The thresher drum, which comprises eight rubber-faced bars bolted on to three steel discs, is vee-belt driven, the speeds being adjustable from 750 to 1600 r.p.m. Two "venetian blind" chaff sieves are incorporated in the machine, the upper of which is the coarser of the two. Its function is to remove most of the large pieces of straw and unthreshed heads. Behind it there is an open wire rake which allows the unthreshed heads or any loose grain to crop into the tailings conveyor. The lower sieve is of finer mesh ; it separates any heads which may have passed through the upper sieve and delivers them to the tailings conveyor, the clean threshed grain passing through to the grain conveyor. A wooden straw rack, which has three fins, opens up the straw to assist complete separation of the grain, and should any grain pass through the rack it is returned to the front of the chaff sieves by an oscillating tray.

Fig. 13—Tractor-driven combine harvester with cutting width of 4ft.

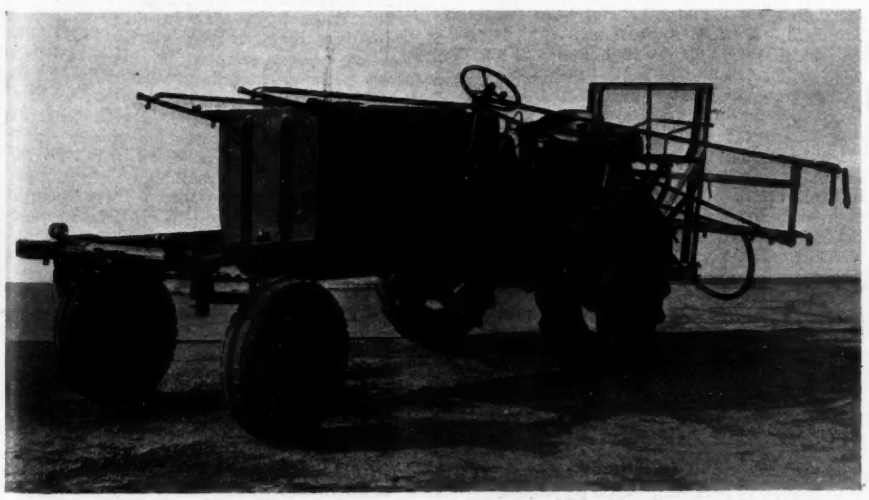


Fig. 12—150-gallon high/low volume sprayer mounted on tool carrier

Feeler Gauges

A SET of feeler gauges in a new form of dispenser holder has been introduced by Rubert and Co., Ltd., Chapel Street, Stockport Road, Levenshulme, Manchester, 19. The blades in the new design of holder are not arranged in the familiar "fan" and pivoted at one end, but are packed in a slot where they are held by a spring clamp, the trigger of which also serves as a pocket clip. Pressure on the trigger of the clamp releases the blades, which can be drawn or tapped out of the holder.

One end of the holder slot is widened so that when it is required to select a feeler blade the whole set can be partly withdrawn and "fanned" to expose the dimensions engraved on the blades. When the required blade has been selected the remainder are pushed back into the holder slide. Then, on the clamp being released, the blade is firmly held with only the length required for use projecting.

Blades are available in thirty thicknesses from

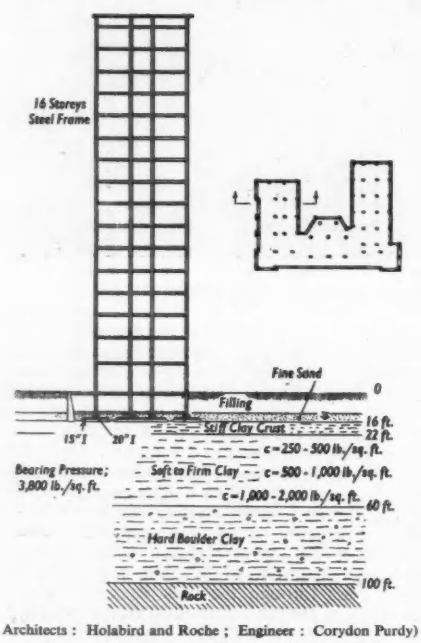
0·001in to 0·025in for use with the holders and sets including the required range of blades can quickly and easily be built up and inserted in a dispenser. The arrangement permits a series of blades to be arranged in steps so that gaps can be measured in one operation instead of inserting a series of blades. Each blade is 4in long and tapered from ¼in wide at one end to ⅛in wide at the other end, and either end can be arranged to project from the holder as required.

Foundations for High Buildings*

By ALEC WESTLEY SKEMPTON, D.Sc. (Eng.), A.M.I.C.E.†

The construction of high buildings, made possible for the first time some sixty or seventy years ago by the passenger lift and the steel frame, has been a great stimulant in foundation engineering. The improvements in construction methods, in structural design and in soil mechanics, which have taken place during this period, and particularly in the past twenty-five years, have made it practicable to construct high buildings on all but the worst ground.

BEFORE the development of the passenger lift, which became a practical proposition[1] in the 1870s, domestic and office buildings were necessarily restricted to five or six storeys. By 1879, however, nine-storey luxury flats in Kensington had been completed by Norman Shaw, and in 1882 the ten-storey Montauk Block office building in Chicago was constructed by Burnham and Root. Those and other buildings of comparable height at that period still had

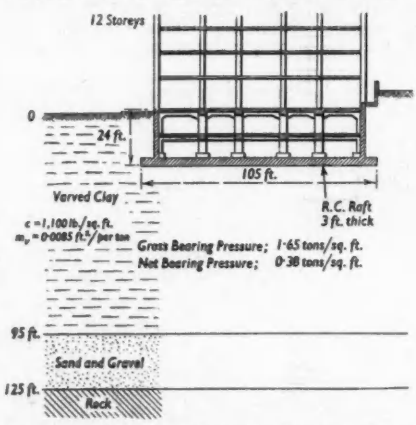


(Architects : Holabird and Roche ; Engineer : Corydon Purdy)

Fig. 1—Marquette Building, Chicago, 1894

load-bearing external walls—a form of construction which is too heavy and cumbersome for structures of more than about twelve storeys. The next essential step was the introduction of the metal frame with light panel walls ; this was first achieved by W. L. B. Jenney (1832–1907) in the nine-storey Home Insurance Building in Chicago in 1885. Five years later Jenney completed the sixteen-storey Manhattan Building, with carefully designed wind bracing, and Burnham and Root, with Corydon Purdy as engineer, erected the first all-steel frame building also in Chicago. In 1892 the first twenty-storey building, the Masonic Temple, was constructed in the same city by E. C. Shankland (1854–1924). The initiative then moved to New York, where in 1898 the twenty-six-storey Park Row Building was completed, with nine electric passenger lifts. The thirty-six-storey Singer Building by Ernest Flagg established a new record in 1908, but the thirty-eight-storey Metropolitan Life Building was finished only a few months later, and both were eclipsed by the first of the giant skyscrapers, the fifty-storey Woolworth Building, completed in 1913 by Cass Gilbert with Gunwald Aus as engineer.

Thus, in the space of thirty years, from Jenney's designs for the Home Insurance Building to the completion of the Woolworth Building, the skyscraper was born and reached maturity. Most of these early high buildings served the purpose of providing more office accommodation



First compressed air caissons for building foundations (Francis Kimball)

Fig. 2—Manhattan Life Insurance Building, New York, 1894

in business centres of restricted area. During the past twenty-five years, however, it has become widely recognised that, without overstepping accepted limits of population density or of floor space ratios,[2] it is possible greatly to increase the open space on a given site by concentrating the majority of the accommodation in one or more high buildings instead of almost covering the whole site with buildings of moderate or low height. The increase in open space improves the daylighting of the rooms, provides more fresh air, relieves the parking and traffic problems, and virtually eliminates the risk of spreading fires. Hence, the demand for high buildings is no longer encountered exclusively in the centres of great commercial cities ; they are increasingly required in many parts of the world, with correspondingly varied foundation conditions.

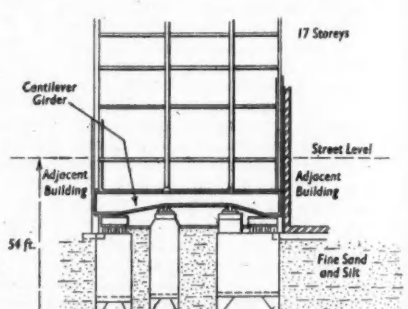
For the comparatively small buildings of traditional construction, the equally traditional foundation types, such as brick footings, timber piles, and masonry or mass concrete rafts, were usually, but not always, adequate. On soils of low bearing capacity the brick or masonry pyramidal footing had to be very massive in order to obtain a sufficiently wide base ; in the Home Insurance Building, for example, of only nine storeys, the footings occupied most of the space in what would otherwise have been the basement. A major improvement was the steel grillage, first used for the foundations of a complete building in 1885 by J. W. Root (1850–1891) in the eleven-storey Rookery Building, Chicago.[3] From that time the grillage, and the later reinforced concrete footings, completely replaced masonry footings for high buildings.

A good illustration of an early Chicago steel-frame structure with I-beam grillage foundations is provided by the sixteen-storey Marquette Building, completed in 1894 by Holabird and Roche with Corydon Purdy as engineer—see Fig. 1. The gross bearing pressure is 3800 lb per square foot on a stiff clay layer underlain by soft clay about 40ft thick. But the net pressure is reduced to about two-thirds of this value, on account of the 10ft basement, and the settlements have not been excessive.

As the column loads increased with increasing height of building and also to avoid danger from future adjacent and deeper excavations, the concrete pier was developed. First used by Sooy Smith (1830–1916) in 1893 for part of the Chicago Stock Exchange and in the same year by Francis Kimball for the seventeen-storey Manhattan Life Insurance Building in New York—see Fig. 2—this type of foundation rapidly became standard for heavy buildings in localities where rock or very hard soil could be reached within about 100ft below ground water level.

Throughout the nineteenth century, and at all earlier periods, the only form of piled foundation for buildings available to the engineer was that of the driven timber pile. During the past fifty years a great number of improvements and alternative types of piling have become available, which cannot be detailed here. Precast reinforced concrete piles were first used by Hennebique (1843–1921) in 1898 and various in-situ concrete piles, which largely eliminate the vibrations associated with driven piles, have been developed more recently, whilst the valuable H-section steel pile was first introduced in 1908.

The most striking advances in recent years are, however, those associated with the buoyancy principle, which can be applied in the most thoroughgoing way with deep raft foundations. The idea, expressed in modern terms, that settlement is chiefly dependent on the net pressure, and that in the limit, with a raft, this pressure can be reduced to zero by excavating a basement of such a depth that the weight of soil removed equals the weight of the building, seems first to have been realised in 1785 by John Rennie (1761–1821) at the Albion Mills in London.[4] This heavy five-storey building was founded on a masonry raft constructed, in effect, as an inverted vault at a depth sufficient to reduce very materially the net pressure on the underlying alluvial deposits of the Thames. The more obvious principle of raft foundations, namely, that of achieving the maximum spread



(Foundation Consultant : Leonardo Zeevaert)

Fig. 3—Albany Telephone Building, Albany, New York, 1929

of load to the ground, was also understood and was used from time to time in later years, by means of thick mass concrete mats, of which the earliest dates from 1817 in the Westminster Penitentiary, by Sir Robert Smirke (1781–1867). But these types of raft were not altogether satisfactory ; the inverted vault was costly and the mass concrete either failed or required to be so thick as to offset appreciably the gain in bearing area.[5] Consequently, it was not until the introduction of reinforced concrete[6] that the raft began to be widely used, and in the early examples such as the raft for the seventeen-storey Michigan Central Terminal,[7] Detroit, in 1914, the buoyancy effect seems not to have been considered, although the excavation was 27ft deep. Whether this effect was consciously used in design before 1928, it is difficult to say, but in that year Daniel E. Moran (1864–1937) designed the foundations of the twelve-storey Telephone Building, Albany, New York—see Fig. 3—incorporating not only

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* Abstracts from one of four papers forming a symposium on high buildings. Institution of Civil Engineers, December 7th.

† University Reader in Soil Mechanics, Imperial College, London.

[1] The references are given in the original paper.

[2] Floor space ratio = total floor area per unit area of plot. If this ratio is 5, for example, the plot would be covered entirely by a five-storey building, but a twenty-five-storey building would leave 80 per cent of the site as open space. The Lever Building in New York is an admirable instance of this principle.

[3] Root had used grillage foundations for a few of the columns of the Montauk Block, completed in 1882.

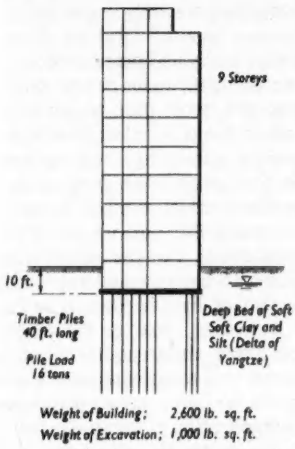
[4] The mills were powered by three 50 h.p. Boulton and Watt engines. This description was quoted in 1870 by Hagen, who mentioned the principle of buoyant foundations. The author is indebted to Professor Terzaghi for this reference.

[5] The three-storey warehouse at No. 19 Berth, London Docks, built in 1842, was founded on a lime-concrete raft 7ft thick.

[6] Occasional use was made of a grillage raft, as for the nineteen-storey Spreckels Building, San Francisco, in 1897.

[7] Designed by George H. Webb.

the buoyancy principle but also making the beams and columns in the double basement act as a Vierendeel truss, and thus form a rigid frame, to reduce the differential settlements.[8] Moreover, the settlements were calculated in advance from tests on undisturbed samples. The success of this foundation, in overcoming difficult soil conditions, has led to the use of deep-raft and rigid-frame basements (often in the form of box frames) for a number of important high buildings on clay during the past twenty-five years, as well as for the proposed twenty-five-storey tower block of the Shell Centre[9] on the South Bank, London, and the thirty-eight-storey High Paddington project, where the London clay extends to a depth of 200ft.

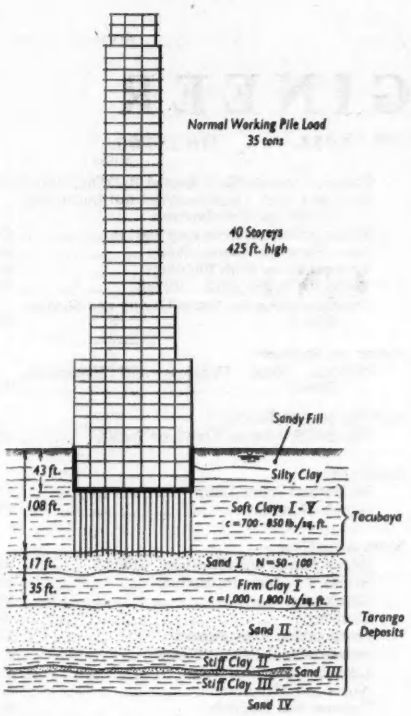


(Public Works Department)

Fig. 4—Ward Road Hospital, Shanghai, 1931

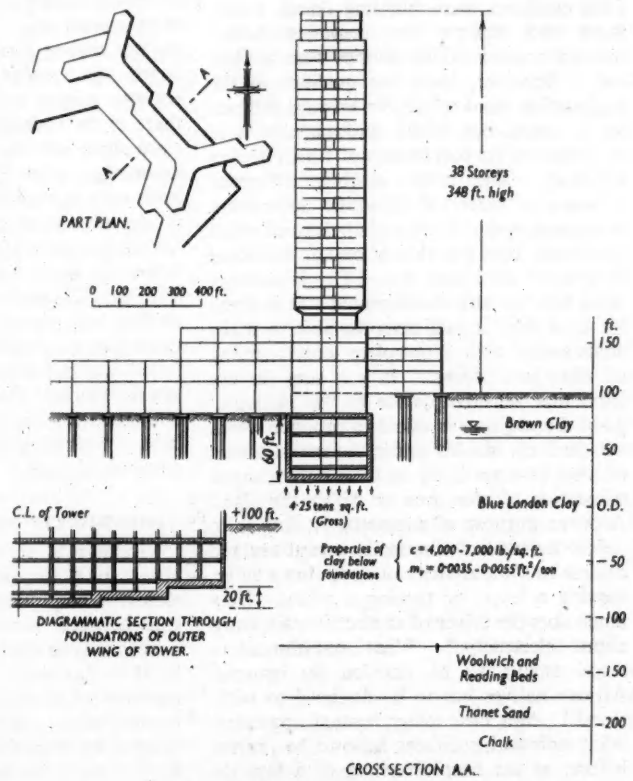
The reduction of net pressure by excavation and one or more basements can, however, also be used with advantage in conjunction with piled foundations, and the first examples were probably the buildings in Shanghai erected in 1932 by the Public Works Department,[7] one of which is illustrated in Fig. 4. Here, again, a number of important applications can be quoted, but the most outstanding is the foundation for the recently completed forty-storey Latino Americana Building, designed by L. Zeevaert, in Mexico City, where some of the older structures of low height with conventional foundations have settled differentially by several feet.

In summary, then, modern techniques have provided three classes of foundation : spread footings of reinforced concrete or steel grillage, which are the simplest; rafts of reinforced concrete, which provide the maximum spread of load ; and piles of timber, [steel] or reinforced [concrete, either precast or] cast-in-situ (and concrete piers), which transfer the loads as deep as possible. Moreover, each class can be used either with or without a basement. If there is a basement the net pressure is reduced and the average settlements will also be reduced whilst, at the same time, the basement can be made sufficiently rigid to minimise differential settlements. All these types of foundation have been developed during the past fifty years, with the exception of the the timber pile, and some only during the past twenty-five years ; yet perhaps the most important single advance in foundation engineering has been the introduction of scientific methods of design. Many have contributed to that advance, but none more than Professor Karl Terzaghi, and of his papers on the subject few have been so influential as that read before the American Society of Civil Engineers in 1927. This date marks a turning point before which the engineer had to rely almost solely on experience and after which, to an increasing extent, experience could be supplemented by design methods based on a rational knowledge of soil mechanics.



(Architects : Kadleigh and Horsbrugh ; Foundation Consultants : A. W. Skempton, associated with Ralph Freeman and R. T. James)

Fig. 6—High Paddington



(Foundation Consultant : Daniel E. Moran)

Fig. 5—La Latino Americana Building, Mexico City, 1953

The box frame or girder type of deep foundation is probably the most useful for the high buildings that will be built in the future in London. The strength of the London clay increases, and the compressibility decreases, appreciably with depth. Hence a deep basement reduces the net pressure and provides a stiff substructure, and also throws the stresses into harder clay. A sketch section through part of the High Paddington project is shown in Fig. 6. For the tower structures of this scheme the author has proposed basements 60ft deep, stepped up to increase the net pressure under the ends of the projecting wings ; and with this foundation the allowable pressure under the centre of the tower blocks, compatible with reasonable settlements, was found[10] to be 1 ton per square foot net or 4¼ tons per square foot gross, and in consequence it could be recommended that a height of thirty-eight storeys was practicable.

The most remarkable application of the combined deep basement and pile foundation, and one of the most advanced works in foundation engineering, is the design made in 1950 by Professor Zeevaert for the forty-storey Latino Americana Building in Mexico City[11] (Fig. 5). Here a 43ft basement has been constructed and piles driven to a depth of 108ft below street level to a layer of sand 17ft thick. Below the sand are several beds of compressible clay, but the decrease in net pressure caused by the excavation is sufficient to prevent the settlements in these clays from reaching a magnitude that would be harmful to the building. During construction the water pressure in the sand layers had to be reduced by ground water lowering in order to safeguard the excavation ; and to prevent settlement of adjacent buildings, resulting from the induced consolidation of the clay layers, the water pumped from the sand beneath the excavation was injected into the sand under these buildings to avoid the seepage gradients that otherwise would have been set up in the clays.

Technical Reports

A Study of the Interreflection of Daylight Using Model Rooms and Artificial Skies. National Building Studies Research Paper No. 24. H.M.S.O., for D.S.I.R. Price 2s. (50 cents U.S.A.) ; by post 2s. 1½d.—Studies which D.S.I.R. has been carrying out since 1947 on the interreflection of daylight in rooms have had two objectives : to answer specific problems relating to schools and hospital wards, and to devise a simple but reasonably accurate method for calculating the total daylight factor at a point in a room, taking into account reflected light. Of the work so far completed, the investigation of a new ward design has been described elsewhere, while the natural lighting of schools is dealt with in the present paper. A more fundamental study, which as yet is only partially complete, will take into account most of the relevant variables over a wide range. In the schools investigation use was made of a model room and an artificial sky, the brightness of which varied down to that of a densely overcast natural sky. This was felt to be more realistic than the uniform brightness assumed in previous research. It was found that for rooms with large side windows and interior surfaces with a high reflection factor, the reflected component of the illumination could be up to four times the direct component. Compared with the model results, which have since been confirmed by full-scale measurements, the old theory, based on a uniform sky and complete absence of reflection, seriously underestimates the daylight available. Calculation of the total daylight factor as a function of distance from window, ceiling height, and various internal reflection factors, is facilitated by the use of a simple slide rule which will be commercially available.

[8] Professor Beggs was associated in the structural design with Moran and Proctor.

[9] Architects : Easton and Robertson ; Engineers : Scott and Wilson, Kirkpatrick and Partners.

[10] From stress calculations and tests on undisturbed samples taken from a boring 140ft deep on the site.

[11] Information supplied by Professor Zeevaert. It may be noted that the new university, with three fourteen-storey buildings, is situated in the Pedregal district 5 miles south of the centre of Mexico City, where the ground consists of volcanic rock.

THE ENGINEER

Vol. 198 DECEMBER 17, 1954 No. 5160

LEADING ARTICLES—
Scientists and Engineers 850
Motorways and High Buildings... 850

ARTICLES—
Anti-Backlash Device for Precision Mechanisms. (Illus.) 858
Automatic Control of Glass Level in Melting Tanks. (Illus.) 858
B.E.A. Policy on the Reduction of Air Pollution 833
Biscuit Warehouse with Pallet Handling 858
Bridge Across the River Volta. (Illus.) 861
British Engineers' Association 833
Calculation of Losses in Transformer Cores. No. I. (Illus.) 837
Clarification of Surface-Water Sewerage Theory. No. I 835
Combined Tension and Torsion Machine for Relaxation Tests. (Illus.) 834
Examination Courses in Plant Engineering ... 833
Feeler Gauges 847
Foundations for High Buildings. (Illus.) ... 848
Glass Fibre Reinforced Plastics in the Chemical Industry. No. I 839
Heavy-Oil Engine Working Costs 833
High-Speed Laboratory Mill 842
Lloyd's Rules for Modern Cargo Ships 833
Machinery at the Smithfield Show. No. III. (Illus.) 847
Melting Shop with a 60-ton Electric Arc Furnace. (Illus.) 843
Partnership of Science and Engineering 852
Precast Concrete Shell-Roofed Building. (Illus.) 855
Prospects and Opportunities in Engineering Design and Development 856
Smoke Pollution Observing Station 833
Spare Parts and Convertibility 842
Symposium on High Buildings 846
Turbo-Jet Hydroplane. (Illus.) 861
Ventilated Silos for Grain Drying and Storage. (Illus.) 859

AMERICAN SECTION—
National Metal Congress and Exposition. (Illus.) 862

LETTERS TO THE EDITOR—
Force of Friction at Very Low Speeds 851

OBITUARY—
Sir Herbert Alker Tripp 851
Joseph Maudslay 851

NEWS AND NOTES—
British Patent Specifications. (Illus.) 867
British Standards Institution 868
Catalogues 868
Contracts 866
Forthcoming Engagements 868
Industrial and Labour Notes 865
Launches and Trial Trips 868
Notes and Memoranda 866
Personal and Business 866
Technical Reports 849

SCIENTISTS AND ENGINEERS

We doubt whether any pure scientist has ever fully grasped what it is that engineers do. Some of them almost totally misapprehend it. Without sufficiently examining the history of engineering, they appear to think of engineers as in some degree their inferiors ; as people merely applying to useful purposes the discoveries that scientists have made. They even appear sometimes to regard them as delinquents who fail satisfactorily to perform their job ! Sir Edward Appleton, whose lecture before the North-East Coast Institution of Engineers and Shipbuilders we reproduce upon another page of this issue, did not fall into any such error. For, like many another scientist, he worked during the war in collaboration with engineers and conceived in doing so a high estimation of their abilities. It is indeed very remarkable that a scientist should be able to speak with appreciation and admiration of inventors who have " pleasure in rejecting, at least for a time, accepted laws and theories." He appreciates, also, as some scientists do not, that engineers have never been " content to wait on scientific progress." Where would the world be if they had ? There is hardly an engineering production to-day which could have been made unless engineers had proved willing to make it upon a groundwork of good sense and intuition, to learn by trial and error what can and what cannot be done, and to derive admittedly empirical and inexact but still very practical formulæ to guide them in design. Upon what a paucity of scientific information was the first steam engine designed and built ! Yet it worked. How very much more we should like to know about creep and fatigue and a thousand other subjects. Yet the plants, machines and other devices that engineers make still work and prove reliable.

Far from the scientist providing all the basic discoveries for engineers to apply, it has been, at least as often, the engineer who has made the discoveries, leaving the scientists to " explain " them later on. The steam engine was in use for over a century before Carnot expounded the theory of heat engines. Civil engineers were building dams, waterways and bridges for centuries before relevant constructional theories were worked out. Moreover, there are qualities in the engineering mind which Sir Edward did not touch upon, but which undoubtedly have relevance to the partnership of which he was speaking. The more obvious difference between a piece of scientific laboratory equipment and the full-scale industrial plant developed from it is that of scale. But there is another difference too. The laboratory equipment is fully instrumented ; it is cared for by a fully trained scientist able to make adjustments with a complete understanding of what he is doing. It is a very far cry from that sensitive device to the industrial plant the engineer is asked to produce which will perform reliably under the ministrations of men who are likely to have only a vague perception of what goes on within the plant. A prime purpose of engineers, in fact, is to reduce the control of complex operations and devices to the simplicity of operating a valve, moving a lever, or turning a wheel. How much does the driver of an electric train know about electricity ? What punishment a diesel engine to be handled by ignorant African natives has to be designed to withstand ! And how many laymen appreciate what technical problems have to be solved before, at the simple turning of a tap, the morning bath can be filled with water ; or drained of it just as simply by pulling out the plug ? Laboratory equipment is fit only for scientists to play with. But many a complex engineering product must be so sturdy, so reliable and so simple to operate that it can be placed with confidence in the hands of those with no scientific or technical knowledge at all !

As a conclusion to his lecture Sir Edward quoted some famous words from Francis Bacon. " For there is no comparison between that which we lose by not trying and by not succeeding ; since by not trying, we throw away the chance of an immense good ; by not succeeding we only incur the loss of a little human labour." But we do not think Sir Edward really had much need to " pass on the same thought " to his partner the engineer. It is true that, more particularly between the wars, many things were not tried by engineers in this country that ought to have been tried ; and that foreign nationals developed a number of scientific discoveries made in this country. But the blame did not, we think, lie at the engineer's door. For the normal reaction of an engineer to any new and apparently sound idea is that of Francis Bacon, to try it and see if it works. But at the elbow of an engineer there always stands an accountant. It is all very well to claim that some new device will prove to have great advantages in a certain application ; certainly the engineer would like to try it. But what if it is unsuccessful ? In the technological sense " we only incur the loss of a little human labour." But in the accountant's sense some tens of thousands of pounds may have been lost ! Indeed, we salute with profound respect those industrialists (not always engineers or technologists) who are prepared to risk experiments with costly equipment. For after all safety always appears to lie in conservatism. One cannot seem to go very far wrong by choosing to use the old well-tried device or method. All the risk lies with the new experimental one. No one can be cashiered for not risking money ! It is this monetary factor that makes so great a difference between science and technology. In science there is no such thing as complete failure, since there will be an accretion of scientific knowledge, even if a series of experiments leads only to negative results. But because it is the object of engineers to apply their knowledge not merely as with scientists to extend it, there *are* failures in engineering, like the Kitson-Still locomotive and rigid airships and many another forgotten project upon the development of which engineers toiled without avail. The accountant who stands behind the engineer makes little allowance for any increase there may have been in technological knowledge. He always demands a profit !

MOTORWAYS AND HIGH BUILDINGS

Visualise a series of elegant buildings about 100ft in height, and stretching in almost a continuous line across a city, the gaps between them spanned by bridges, and a motorway extending along the route formed by their flat roofs, with access " spurs " at intervals of about a mile, running down to ground level. That is the conception envisaged by Wing Commander Cave-Browne-Cave in his prize-winning essay in the Royal Society of Arts' competition on " Life in the Year 2000." The essay placed second in the competition, written by Mr. C. E. H. Watson, foresees a fascinating succession of engineering progress, its principal theme concerning the creation of a system of radial and ring roads, built in deep tunnels in the chalk underlying London. The competition called for " a single practical aspect of life on this

earth in the year 2000," and thus the schemes envisaged may seem rather extravagantly conceived when judged by to-day's yardstick. For instance, the " spurs " of the roof top roadways would need to be of a gradient of about 1 in 30 (the author suggests 1 in 10 or 12), and so each spur would be about half a mile in length ; there would be a similar problem in the second scheme. But it is not a criticism of the schemes themselves which interests us principally ; the significant fact is that both the winning competitors chose the same subject of road communications in London as their central theme, thus recognising perhaps the greatest problem facing Greater London to-day, and a problem which is equally serious on a national scale. The discussion following the reading of the two essays also centred more on road problems to-day than on life fifty years hence, so we may infer that the practicability of both schemes was unquestioned even though their economic value was not.

The two essays, when read in detail, clearly show the close relationship between the difficult task of providing safe and efficient road communication in a city, and the more general conception of town planning. It seems fundamental that town planning schemes should be based on, and developed round, an adequate road system, and the lack of appreciation of this principle has been one of the handicaps which have reduced much post-war town and country planning, particularly in Central London, to the by-law level, rather than leading the way with creative conceptions of a better city. Even the Royal Society of Arts' essays may leave us dispirited (the Society itself did not award the full first prize—the standard of entries was considered disappointing) when considering the future of London and other cities. But last week another learned society—the Institution of Civil Engineers—held a meeting at which similar problems were discussed. It provided more sanguine reasons for optimism. The occasion was a symposium of four papers on high buildings, and was particularly interesting because of the diversity of professions, apart from the Institution's own members, represented in the discussion. Three of the papers concerned technical aspects of the main theme ; they were important papers, and they are summarised, and one of them reproduced in abstract, elsewhere in this issue. However, it is the opening paper by Mr. Kadleigh which attracted the more general interest. Most of us associate tall buildings with canyon-like streets, congested because of the vast accommodation towering beside them. But under a more sophisticated notion the tall buildings would each stand in spacious grounds, freed from development by concentration of accommodation in the tall central block. The conception elaborated by Mr. Kadleigh goes still further than that, and envisages a building, twenty to forty storeys in height, housing a community of 5000 or 10,000 people, with all the varied amenities of a small town, including open spaces and a town centre, within the confines of the one structure. In his own words, " Such a form of development should not, of course, be confused with the idea of a huge block of flats. It is conceived on entirely different principles, the principles of a hill town complete with all the social and economic requirements for a prosperous community ; sweeping views, clear air, noble skies, spacious promenades and hanging gardens that one associates with the delights of living in high places. At the foot of this hill town, industry and commerce, astride road and rail, transport in the very heart of the city and within walking distance of its labour, have all the material conditions for a prosperous community." Such an idea makes an assault on the basic principles of town planning as they are now practised in this country. It envisages the " multiple use of land," and is scornful of " decanting overspill," the purpose of the satellite towns, as described by town planning jargon. The " High Paddington " project, a structure of the kind described which would be built over Paddington goods yard, is an example of the general concept ; that its design conforms to accepted engineering practice may be seen from the brief note on page 849, outlining the design of its foundations. When it is considered how conservative we are, as a nation, over innovations in our building, it seems surprising how well Mr. Kadleigh's thesis was received at the " Civil's " meeting. It did not escape unscathed by criticism, and the practicability, and of course the cost, of such a scheme were both questioned. But the general trend of the discussion left little doubt that there were ample and sufficient grounds for building at least one of these structures, to see how the " hill top " community worked out in practice. So we are particularly interested to note that a considerable volume of detailed engineering investigation has been carried out for the High Paddington project, although whether it will in fact be built cannot yet be said. Such a building is not divorced from our earlier discussion on roads. The multiple use of land, the freeing of space around the " hill top " community, and the need for good communications serving it, would all tend to favour the provision of a trunk motorway system in the nearby central area, in addition to the compelling reasons which otherwise obtain. Given a successful result with the first of these " hill top " towns, a dozen or more of them may be envisaged spaced around the Central London area, with ring and radial motor roads linking them and perhaps passing through or under them. Such development, carried out circumspectly, would not detract from the traditional charms of Central London, but would afford a rational development, blending, traditionally, the best of old and new alike.

Obituary

SIR HERBERT ALKER TRIPP

On Monday last, Sir Alker Tripp died at the age of seventy-one years. Sir Alker joined the Metropolitan Police Force in 1902, and from 1932, after he had been appointed an Assistant Commissioner at Scotland Yard, he was closely concerned with the traffic problem in London. As head of the rapidly growing traffic department he directed his energies to the study of traffic control and road safety. Sir Alker saw the need for a co-ordinated traffic policy in London and a master plan for highway development. In this connection he presented a paper, " The Design of Streets for Highway Traffic Requirements," to the Institute of Transport in 1933, and for this paper he was presented with the gold medal of the Institute.

From 1933 to 1947 Sir Alker served as a member of the London and Home Counties Traffic Advisory Committee. He made a close study of traffic conditions in large cities abroad and in 1938 he published his well-known textbook *Road Traffic and Its Control*. In 1942 he published another book entitled *Town Planning and Road Traffic*, in which post-war reconstruction suggestions were combined with the results of his investigations and practical experience in traffic control. That same year Sir Alker became a member of the Royal Academy's Planning Committee for the architectural redevelopment of London. In addition to his official activities, Sir Alker was also a well-known yachtsman, artist and author. He was made a C.B.E. in 1935 and was knighted in 1945.

JOSEPH MAUDSLAY

It is with regret that we have to record the death of Mr. Joseph Maudslay at the age of seventy-four years on Friday last. Like his father, Herbert Charles Maudslay, he was an engineer, and following his education at the Isle of Wight College he qualified as an engineer and entered the service of the Egyptian Government in 1903. He served in the 1914–18 war and after returning to Egyptian service he was appointed assistant general manager to the Egyptian State Railway in 1921, a post from which he retired three years later.

During the last war Mr. Maudslay was employed by the Ministry of Supply and was commandant of the depot at Pontrilas, Herts, until 1945. He was elected president of the Maudslay Society in 1945.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

FORCE OF FRICTION AT VERY LOW SPEEDS

Sir,—Mr. Tarrant*, in an article on " Measurement of Friction at Very Low Speeds," in your issue of August 20th, observed that the " ball seating" of one of the platens of a concrete testing machine did not move freely. In order to examine this question he applied two proving rings of different stiffness so that on applying load to the machine the two rings were deformed through different distances, thus causing the platen to rock on its seating. The difference between the loads carried by the two rings gave the couple required to cause the platen to move until the difference in load owing to unequal elastic deformation vanished. During this relaxation period the sum of the force of deformation gave the total load on the seating, and it is worth bearing in mind that in the course of this interval of time the acting couple decreases. It appears from Mr. Tarrant's description that the relaxation period was of the order of one hour and the movement of the ball seating about 0·6cm. This would mean an average speed of relative motion of the order of $1 \cdot 7 \times 10^{-4}$cm per second.

If one were to consider such an experimental set-up for the measurement of the force of friction one would have to record on a time base the relative motion between the two friction elements since the relaxation of the shock load might proceed by deceleration or by a series of jerks. It is indeed questionable whether shock loading is a good way of triggering off a frictional contact with the aim of acquiring knowledge concerning the force of friction and it is certainly not enough to measure or record the deformation of part of the supports. There is

* " Measurement of Friction at Very Low Speeds ", A. G. Tarrant, The Engineer, Volume 198, page 262, 1954.

the further difficulty with the arrangement described by Mr. Tarrant of the propelling couple decreasing in magnitude during the course of an experiment. At a nominal bearing pressure of 1000 lb-wt. per square inch it is quite in accordance with expectation that the degree of surface finish of the friction elements did not affect the results.

"Extreme-pressure" lubricants are designed for operation at actual bearing pressures of at least 15,000 kg-wt. per square centimetre. If there is an appreciable difference in performance of the experimental set-up with a proven "extreme-pressure" lubricant on exceeding a nominal bearing pressure of 70 kg-wt. per square centimetre (1000 lb-wt. per square inch) this is a reflection on the suitability of the experimental arrangement for measuring the force of friction.

ROBERT SCHNURMANN
HENRY JAMES BEZER

Physics Department,
Manchester Oil Refinery, Ltd.,
Manchester.

SIR,—Mr. Schnurmann and Mr. Bezer must, I think, be under some misapprehension as to the experimental technique described in my article. Their use of the terms "shock" and "relaxation" convey the idea that the load was applied to the testing machine *suddenly*, and was allowed to even itself up gradually : they suggest over a period of about one hour. I do not, myself, see how such a process would work, or what results it would give ; it is certainly nothing like that which I used. In my work, the load on the testing machine was increased slowly and smoothly from zero up to a predetermined limit, the differential yield of the two proving rings caused the platen to tilt slowly and smoothly, and the couple causing that movement was indicated by the difference between the loads on the two rings. At the same time, the sum of those loads gave the total force on the platen seating. The testing machine operator kept the pointer of this dynamometer moving steadily round the dial, and signalled as it passed certain predetermined loads ; two other operators noted the simultaneous readings of the proving ring dial gauges. There was no question of either shock nor relaxation occurring.

Admittedly, it would have been more convenient if self-recording strain gauges had been used, but the writer's problem did not warrant the necessary installation work. One purpose of the article was to suggest that this method should be developed by others who are concerned with more extensive studies of friction.

I entirely agree with your correspondents that 1000 lb per square inch is a trivial load for an extreme pressure lubricant *in ordinary use*—that is, when motion is occurring fairly rapidly, and when hydrodynamic or externally applied forces are present to maintain the film of lubricant between the rubbing surfaces. In such conditions the special properties of "E.P." lubricants are most useful in protecting the surfaces from the effects of any heat that may be generated. But the conditions in a testing machine are entirely different—there the necessary requirement in a lubricant is that it shall adhere to the bearing surfaces by its own molecular attraction, as no other forces are available to hold it in. In these circumstances it is clear that the inclusion of highly polar—i.e. chemically active—molecules is the important thing : the movement is always very slow, so that the need for protection from heat does not arise. It is therefore entirely to be expected that an "acid-finished" grease would prove more effective than a less active material, and that the inclusion of extreme pressure additives, as such, has nothing to do with the case.

A. G. TARRANT

Harmondsworth,
November 22nd.

Partnership of Science and Engineering

By SIR EDWARD APPLETON, G.B.E., K.C.B., D.Sc., F.R.S.

In this the 23rd Andrew Laing lecture, delivered before the North-East Coast Institution of Engineers and Shipbuilders on December 10th, Sir Edward Appleton discusses the respective contributions of science and engineering in our civilisation. He touches upon the characteristics of inventors and technologists and illustrates his account by reference to the development of the thermionic tube and of nuclear energy.

I DO not propose to weary you with a meticulous attempt to specify the dividing line between science and engineering. I would much prefer the boundary to be regarded as an indefinite one—and certainly one without a fence ! But I feel I must insist on one thing and that is to claim that, generally, the pursuit of engineering, unlike that of science, results in something being made—something that is useful, though it may well have other qualities, such as elegance and economy. For this reason I would say that a subject like meteorology and weather forecasting, although an applied science, is not engineering.

It has long been realised that the pursuit of science yields results which are useful as well as interesting. It is worth noting that at different times in the world's history these two aspects of science have received unequal emphasis. For the Greeks the intellectual interest of science was the more important ; they concerned themselves mainly with theoretical reasoning about ultimate causes. The Romans, on the other hand, valued science for its practical utility. For the Greeks science was serenely elevated above the activities of a busy world ; for the Romans it was rather the beneficial support of occupational activities in war and peace. History tells us that the earliest use of the word engineering referred to the activities of those who devised engines of war and who constructed works for military purposes. Here I must digress for a moment to acknowledge an exception to a generalisation I made earlier. I contrasted the theoretical interest of the Greeks with the practical pre-occupation of the Romans. Yet it is recorded that, during the siege of Syracuse in 214–212 B.C., the Greek Archimedes inflicted a terrible defeat upon the Romans and their ships by bombarding them with stones, up to 100 lb weight, ejected from large catapults. These weapons were later copied by the Romans but not with equal success ; and I believe that, even to this day, no one quite knows how these early engineers maintained the force of propulsion by twisting the catapult strings made of rope, hair or sinew. When people have tried to simulate these weapons they have found it difficult to maintain the elastic qualities of the sinews.

Nowadays all the three basic divisions of engineering have their subdivisions and their representative institutions. Of these specialised branches of engineering, two —that is, electrical engineering and chemical engineering—are themselves based on scientific discoveries and, in the course of their lives, have been continually nourished by further developments in the field of pure science. And I suggest that we can see already on the horizon a new specialised branch of engineering—nuclear engineering—to which I shall have occasion to refer, more fully, later in this lecture. Yet one must recognise the fact that the engineer has not been content to wait on scientific progress. Many of the major developments in engineering were founded on extremely rudimentary scientific knowledge. The steam engine, for example, was used for pumping water in England as early as 1712, yet it was not until over a century later that Carnot enunciated the second law of thermodynamics which explained its performance. And almost another century elapsed before Callendar furnished us with a comprehensive understanding of the thermal properties of steam.

At this stage I would like to leave my main theme for a while to touch on the subject of the inventor and inventions. To make a scientific discovery does not mean to make an invention, though that discovery may well extend the area for invention. You will all have noted the different treatment which society at present gives to discoverers and inventors. The only thing a scientific research worker gets, as a result of any discovery he may make, is the credit for having done so. But there is no law to protect his right to such credit. He gets, as we say, no title to it. It is quite otherwise with a patentee who, through his patent, acquires a piece of saleable property. Very often, though by no means always, a scientific discovery will lead to an invention, so long as a new and useful result is obtained. Let me give you a modern instance of what I mean. It has been shown that the sun emits radio waves as well as light waves. That is a discovery. But if the discoverer, or someone else, devises a useful method of employing this fact in finding the position of the sun at sea, in cloudy weather—we might consider such a device a radio-sextant—that might well form the subject matter of a patent. But, of course, a patent need not necessarily involve a scientific discovery, as the zip-fastener well illustrates.

Since inventions have provided the initial nucleus of so many developments in engineering it is worth while at least attempting to identify the characteristics of the inventive step. Such a step, I suggest, must contain more than deductive reasoning. Indeed, my own view is that the impact of an invention on the minds of others, skilled in the art, should engender surprise. The best type of invention is only understood after it has been explained. Inventors must, of course, first identify a practical need. But beyond that they must be people who, while they may have been told, don't believe that things can't be done. Inventors are people who seem to take pleasure in rejecting, at least for a time, accepted laws and theories ; though the best of them may make many experiments in their minds for every one they make on the bench. The more pedestrian of the inventor class try everything, however unpromising, in an effort to get results. In the case of the most brilliant, intuition is highly developed. An invention results from an adventure in a single mind. Teams don't make inventions. Also I may remark that patent-consciousness among some of the members of a team can work havoc with effective collaboration.

The extension of scientific knowledge correspondingly increases the territory in which inventions are made, though many

technologists can now achieve results, as useful as many inventions, by way of reasoning alone. The inventor therefore has a rival, nowadays, in the technologist. But I am sure there is room for both.

I now leave the subject of the inventor and turn to a field of human endeavour where the collaboration between the scientist and the engineer has been so close that it is difficult to disengage it, even in retrospective review. I begin by remarking that sometimes an operation which may be regarded by many as a mundane one has often the most profound influence on both science and engineering. Let me remind you of the enormous importance of vacuum technique in this connection. The problem of evacuating glass vessels containing metal electrodes was really solved during the period of World War I. Before then we had such a sealed-off vacuum tube in the case of the ordinary electric lamp bulb, but the development of the thermionic vacuum tube required a much higher degree of vacuum than had been necessary in a lamp. Moreover, since in operation some of its electrodes are run hot, it was necessary that the metal parts of a thermionic valve should be thoroughly freed from occluded gas before the tube was sealed. One cannot but admire all the thought and invention which have led to present-day achievements in this unspectacular work, but it certainly can be said to provide the technical basis of an entirely new subject, that of electronics. The residual gas pressure in some modern valves may be as low as 10^{-9}mm of mercury. Before World War I the gas pressure in sealed-off electric light bulbs was about 10^{-3}mm of mercury.

It is mainly as a result of these improvements in vacuum technique with their influence on thermionic valve life span that these components can be introduced into unattended electric circuits. You no doubt have read about the courageous project to lay a transatlantic submarine telephone, about 2000 miles in length, in which there will be fifty-two repeaters, employing thermionic valves, spaced at intervals within the cable. The success of this scheme will depend on very few of 300 valves and nearly 10,000 other components developing a fault during the next twenty years or more. These repeaters will be energised by direct current over the central conductor of each cable from the terminal stations. It is proposed that there will be two one-way cables between Scotland and Nova Scotia, and a single two-way cable between Newfoundland and Nova Scotia. As in the more modern types of submarine telephone cables, the transatlantic cables will be of coaxial type. Polythene, a product of the chemist and of the chemical engineer, will be used as insulator. This great project has been designed by the British Post Office and the Bell Telephone Company of the United States. The cables will be laid by the Post Office cable ship "Monarch," which can carry between 5000 and 6000 tons of cable and will lay cable and repeaters as a continuous operation.

This bold enterprise cannot but excite our admiration and good wishes. But I must remind you that the modern hard thermionic tube resulted, in large measure, from purely scientific experiments on the emission from hot metal wires. The first theory of the electrostatic action of a grid was given—though, of course, not in this connection—by Clerk Maxwell. The development of the gas-filled, and therefore erratic, audion of de Forest to the highly evacuated, and therefore stable, thermionic tube of to-day is the result of the further work of many other minds and hands. Without the thermionic vacuum tube—the joint child of the physicist and the radio engineer—the world would be a very different place altogether. The reason for this is that the valve has greatly expanded the scope of our most natural mode of communication—by the voice and by the ear. Nation now speaks unto nation with ease and clarity.

However, let us note here the beneficial interplay of science and radio engineering. The modern thermionic valve is the primary tool of radio, radar and television. But it is also the primary tool of many purely scientific investigations. Let me instance here the rapidly developing subject of radio-astronomy, which is revolutionising our ideas about the radiations reaching us from outer space.

I now come to the most important recent application of physical science in the field of engineering. I refer, of course, to the methods of releasing energy, in a useful form, from the nuclei of atoms. You will notice that I used the phrase "in a useful form," since it is necessary to emphasise the fact that the discovery of nuclear fission alone, while of great scientific importance, would not in itself lead to any consequences of engineering importance. The important discovery was made that nuclear fission, stimulated in the first instance by neutrons, can result in the emission of further neutrons which can continue the chain of similar events. Under suitable conditions the release of energy is self-sustaining so long as the fuel lasts, as in a fire.

The engineer is naturally interested in the form of the energy resulting from nuclear fission. In the case of the disruption of the uranium 235 nucleus, 83 per cent of the released energy appears in the form of the kinetic energy of the atomic fragments resulting from the fission, about 11 per cent of the energy becomes available later as a result of the radioactive decay of these fragments, 3 per cent is to be found in the kinetic energy of the emitted neutrons and 3 per cent in the electro-magnetic radiation (γ-rays) emitted instantaneously at the moment of fission. By far the greatest amount of the nuclear fission energy is therefore to be found in the kinetic energy of the fragments. And it is interesting to note that, if we consider this kinetic energy as developing from the flying apart of these fragments as a result of their mutual electrical repulsion, assuming their initial distance apart to be of the order of nuclear dimensions, we derive a figure for their kinetic energy which is very close to the experimental value. We can show, in this way, that the fission of one uranium 235 nucleus gives us $3{\cdot}2\times10^{-4}$ erg., or $3{\cdot}2\times10^{-11}$ Joule. Or, to put matters in a more practical way, we need 10^{17} atoms to give us a kilowatt-hour of energy. By contrast I may add that we need at least a million times this number of atoms to give us the same amount of energy in ordinary chemical reactions.

The first self-sustaining pile, generating heat by a nuclear fission chain, was set up by Fermi on a squash court in Chicago University and, on December 12, 1942, developed 200W of power. The construction of this original assembly is interesting because the first British pile for generating electricity in Cumberland is to be a refined version of the original. The uranium in the Chicago pile was in the form of bricks of pure uranium metal and uranium oxide. As a moderator, for reducing the velocity of the fission-ejected neutrons by way of repeated impacts, and so facilitating further fissions, pure graphite was used—also in blocks alternating with the blocks of uranium.

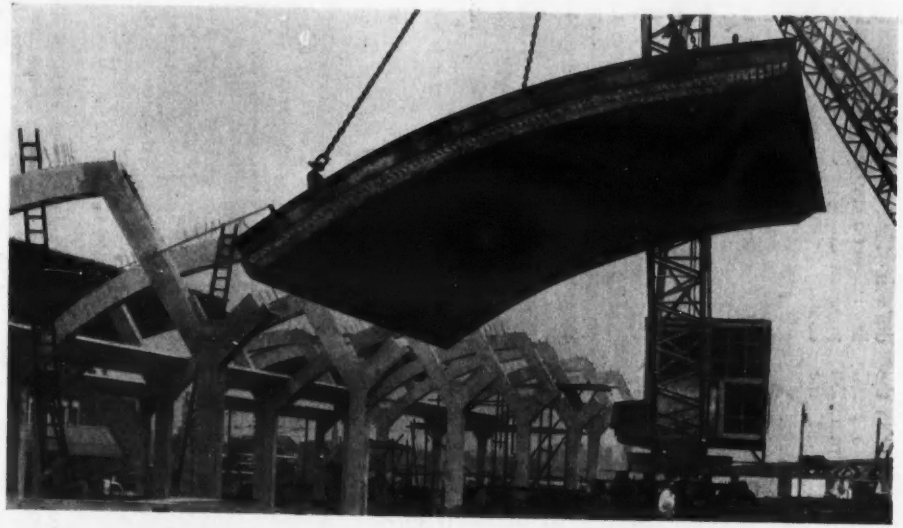
Of course, as I have already explained, in a pile of this kind the heat is generated in the uranium metal in which the radioactive products of fission also accumulate, while a protective concrete shield must be built round the pile to absorb the dangerous radiations issuing from it. Reactors of this kind are called thermal reactors—not because they generate heat, but because of the action of the graphite atoms in reducing the velocities of the fission-emitted neutrons to thermal values. Heavy water or even ordinary water can be used to perform the same function.

In the projected Cumberland pair of reactors the fuel will be uranium and the moderator graphite and the whole will be enclosed in a steel pressure shell. The temperature will be allowed to rise to nearly 400 deg. Cent. Carbon dioxide gas under pressure will be pumped into the graphite-uranium core to take away the heat to four steam generators positioned symmetrically round the pile. The steam-raising equipment will operate an electric power station of the normal turbine type, and electricity will be passed on to the grid. Because of the temperature limitation in the thermal reactor it is not expected that the overall efficiency of conversion of the heat to electricity will exceed 25 per cent.

So far I have been dealing with the simplest type of reactor and certainly the one with which physicists and engineers have had the greatest experience. But there are other far-reaching possibilities. Let me remind you that in a thermal reactor, if natural uranium metal is used, there is only about 0·7 per cent of the fissionable isotope U235 present. The remaining 99·3 per cent is U238. Now the U238 in a thermal reactor is not fissile, but it is fertile—that is, it can absorb neutrons to form a new fissile material, plutonium Pu239. (I might here remark that in this particular context U233, U235 and Pu239 are fissile, while Th232 and U238 are fertile.) Because of these considerations an entirely different kind of power-producing reactor has been contemplated, the so-called breeder pile. In this type of reactor the core would contain a substantial amount of fissile material (e.g. U235) but would also contain a fertile material (e.g. U238). The moderator would be dispensed with and the fission would be effected by intermediate or fast neutrons. While the chain reaction continued, some of the neutrons would be absorbed by the fertile material ; and there is the possibility that the amount of new fissile material produced (e.g. Pu239) would more than compensate for the old fissile material consumed (e.g. U235). In a fast reactor of this type the main engineering problem would be that of taking away the heat from the metal core of fissile and fertile material. A liquid metal coolant—sodium or sodium-potassium alloy—has been suggested. But the immediate outlook here is not so clear and certain as in the case of the thermal reactor.

It therefore seems fairly clear what is immediately on the horizon in the field of nuclear engineering. For you will have seen that the subject is now so far developed that much of the work is out of the hands of the physicist working alone. But I do want to stress that our nuclear engineer will be dealing with problems which, as an engineer—be he civil, mechanical or electrical—he will never have encountered before. Materials will have to take on for him an entirely new meaning. Let me mention just one thing in this connection. In a nuclear pile the magnitude of the neutron flux is all important, and yet materials with much the same mechanical properties have very different powers for absorbing neutrons. Take the case of cadmium and boron. There is nothing mechanically remarkable about them. Yet both of these elements possess high absorbing

PRECAST CONCRETE SHELL-ROOFED BUILDING



Lifting one of the precast pretensioned roof units. Each one is 16ft by 24ft by 2½in thick and weighs 7 tons

Erecting precast frames and gutters. The frames have two basic elements—a combined column and north light strut, and a curved rib

The stressing bed. Timber moulds rest on steel scaffold tubing bedded in mortar, in which they can slide freely and be easily levelled

Aerial view of the site. The stressing bed is on the left-hand side

powers for neutrons. Rods of such materials may therefore be inserted in a reactor to damp down the chain reaction. Then there are supporting chemical engineering problems of a new kind. One, involving physical chemistry, is concerned with separating the lighter fissile uranium constituent, U235, from its heavier relative, the fertile U238, by diffusion through a porous barrier. Chemical separation is out of the question since the two substances are isotopes. A gaseous compound of uranium has obviously to be used and the compound chosen in the work done on the nuclear bomb project in America was uranium hexafluoride. Other methods of separation have been used—one along the lines of positive-ray analysis and the other involving thermal diffusion — but both have been found less generally useful than the simple diffusion method. The other major chemical engineering problem is that of separating a fissile product such as Pu239 when it has been formed by the neutron bombardment of a fertile substance such as U238. The whole reactor metal is then heavily and dangerously radioactive so that the chemical processes have to be carried out by remote control.

In considering the effect of nuclear energy on the world economy there is always the unknown factor of the nature of scientific progress. But taking the situation as it is to-day, without the further possibilities which fundamental research may open to us, it looks as if we must look on fissile material as another form of fuel and nuclear energy as another source of heat. The possibilities of employing usefully the uncontrolled reaction of a nuclear bomb seem to be few—the destruction of obstacles, e.g. a mountain or submarine reef dangerous to shipping. From the engineering point of view, then, it looks as if we must confine our attention, for the time being, to the heat yield of nuclear fission. We are, however, somewhat limited at present by the relatively low temperature at which this heat is produced, though metallurgical progress may well alter the situation at any time. Yet the heat can be delivered at a sufficiently high temperature for district heating to a high-density urban population to be possible. One of the reactors at the Harwell Atomic Energy Research Station is already used for this purpose. Also, as we have seen, steam raising is certainly possible with the consequent generation of electricity. Thinking, then, of the not too distant future, we must think of nuclear energy as a source of electrical power with fissile material as an alternative fuel to coal and oil, or as an alternative to the burning fuel in the sun, which gives us, indirectly, water power and wind power for electricity generation.

The question of interest is the way that this new fuel is going to affect the world's economy—and especially the economy of this country. Our demand for electricity doubles approximately every ten years, and yet we do not use as much electricity per worker as is the case in another highly industrialised country, the United States. With our coal supply getting by no means easier as the years go on, even if our foreign exchange position for the payment of foreign fuel does get easier, it seems to me that our interest in the nuclear energy field should be one of intense preoccupation. I see, ahead, the development of an enormous industry based on technology—the industry of not only supplying ourselves with nuclear electricity generating stations, but of supplying other countries with them and possibly selling them fissile materials which we have ourselves produced from fertile uranium or thorium. The general tendency to-day is for the so-called backward countries to desire to industrialise themselves and this is a tendency which will most likely strengthen as the years go on. Industrialisation, so far as we can see, involves the use of that most flexible form of energy—electricity. One cannot expect, as was the case in the past, that British capital will provide the basis for such industrialisation. Nationalistic feeling abroad will prevent that. But there will undoubtedly be scope for the consulting nuclear engineer abroad, as there has been for the civil engineer and the mining engineer in the past. And, as we well know, the consulting engineer abroad usually finds work for his fellow countrymen at home.

In conclusion I would like to express a few personal views. I regard a close partnership between science and engineering as something which is absolutely vital for our economic progress in this country. At present we are only at the stage of building the first nuclear power plants, knowing that we shall learn much in doing so. The appropriate analogy is with the early days of the steam engine. But I regard it as essential that such nuclear scientific and engineering knowledge as exists should be available to manufacturing firms. We want that knowledge to permeate British industry. Fortunately Sir Christopher Hinton, the Controller of Atomic Energy, has made it clear that he does not regard the Atomic Energy Authority as the organisation for the building and design of the types of such operational nuclear energy plants which are now contemplated. Instead, he has declared that the work should be done by industrial firms.

A revolution in the employment of automatic methods in manufacturing factories, a subject on which I have not touched, seems also ahead of us, and there will be an increasing need for the training of automatic control engineers with mathematical equipment well beyond that of the ordinary engineer trained in our university schools. This development will also call for statesmanship on the part of both management and labour ; for, like many technological advances, it will engender temporary redundancy of staff.

I end this address on an even more personal note. In my own scientific work I have often had occasion to feel the force of one of Francis Bacon's aphorisms, which is to be found in his *Novum Organum*, published in the seventeenth century. It runs as follows :

" For there is no comparison between that which we lose by not trying and by not succeeding ; since, by not trying, we throw away the chance of an immense good ; by not succeeding we only incur the loss of a little human labour."

As a scientist I pass on the same thought to my partner, the engineer.

Precast Concrete Shell-Roofed Building

We illustrate on the page opposite various phases in the erection of the workshop block of the new technical college at Kingston-upon-Hull. This building is of interest because of the precasting techniques used in its construction. It is a single-storey building, 312ft long and 192ft wide, and is planned on a 24ft square grid and is divided into four blocks by 12ft corridors. The new building straddles one end of the site of the Old Queen's Dock, which was built about 1780, and filled in about twenty years ago.

Foundations.—The foundations are piled. Large foundation beams span the dock walls throughout and provide a standard grid of supports for the suspended ground floor. Because of the curve of the dock walls across the site there were difficulties in siting these foundations. They had to be independent of the old structure because the latter's foundations are above the level of the boulder clay which forms the bearing stratum for the block. The piles were cast-in-situ, the casings driven or bored as determined by the varying site conditions. For the majority of the piles the concrete shaft was expanded and consolidated by redriving a smaller casing down the centre ; the remainder have expanded bases.

The reinforced concrete suspended ground floor contains a system of main and subsidiary ducts for services and also incorporate fixed-end sockets for the superstructure columns. Part of the building has a lowered floor for machinery bases, isolated against vibration.

Superstructure.—The superstructure has been erected at a rate of eight bays in two weeks. Full-scale stressing and loading tests were carried out on the precast frames and the shell roof units at the beginning of the work.

The main frames comprise eight-bay continuous portal frames and are clearly shown in the illustrations. There are only two basic precast units : a combined column and north-light strut and the curved rib. The units are erected by Scotch derricks, high-tensile bars inserted, the joints concreted, the bars stressed (using the Lee-McCall system), and finally grouted.

The gutter units are precast on the site, pretensioned sufficiently to withstand handling stresses, and are finally post-tensioned when in position. These gutter units, when connected to the main frames, make a series of portal frames laterally.

Each unit of the shell roof is 2½in thick, measures some 16ft by 24ft, spanning in the 24ft direction, and weighs about 7 tons. They are being cast on the site, in batches of eight, on a prestressing bed, which has been set up in a bay of the previously constructed ground floor. Eight gutter units are cast simultaneously with eight roof units.

The roof units are fixed by laying them on the frames, clamping them down, and placing a filling of in-situ concrete between adjacent units over the frame ribs.

The Prestressing Bed.—The prestressing bed is over 200ft long and the 5-ton jacking head is some 20ft wide. It can be operated uniformly over its full width and the total compressive force is about 450 tons. A rolled steel joist has been cast in the floor to act as a spreader and it is well anchored down.

To avoid bending moments being induced in the floor, vertical steel beams (plated channels) are placed at each end of the bed to anchor the prestressing wires ; these beams are supported by rocker bearings, and the tensional forces are counterbalanced by tie bars buried in drain pipes in the ground 5ft below the floor slab. The pipes permit freedom of movement of the tie bars, which can be reclaimed on completion.

The wires are stressed in pairs by the travelling jack, which has a compensating device in the gripping head ; the load is simultaneously taken up on the tie bars with a jack in order to ensure that the plated channel uprights remain vertical. On completion, the tie bars are gradually released and the entire head arrangement is allowed to pivot about the rocker bearings until all the load is let off.

Concrete.—A high-quality concrete is required. The concrete mix is 1 : 1 : 2 with a water/cement ratio of 0·34. Washed Trent River sand and gravel are used and with rapid-hardening cement 5000 lb per square inch concrete is obtained in two days.

The roof units are lifted in a frame which consists of two shaped channels, one at each end of the unit, welded tubes connecting the channels and a pyramid sling. This frame is fixed to bolts cast in the concrete shell and later burnt off.

The consulting engineers for this work are Messrs. Scott and Wilson, Kirkpatrick and Partners and the architect is Mr. F. Gibberd. The main contractor is William Moss and Sons, Ltd.; sub-contractors for the piling, precast frames, prestressing bars and prestressing wires are respectively Holmpress Piles, Ltd., Trent Concrete, Ltd., McCalls Macalloy, Ltd., and Richard Johnson and Nephew, Ltd.

Guarding Kiln Support Rollers.—We have received from the Cement Makers' Federation, 52, Grosvenor Gardens, London, S.W.1, a leaflet with the above title, published by the Federation's accident prevention advisory committee. Various guards are illustrated, and it is pointed out that the committee would welcome any further advice or comments.

Prospects and Opportunities in Engineering Design and Development

By MAJOR-GENERAL S. W. JOSLIN, C.B., C.B.E., M.A.

At the Institution of Mechanical Engineers on Tuesday, December 7th, a Conference was held on "Mechanical Engineering as a Profession." Its main purpose was to interest school-masters and teachers in the opportunities for boys entering mechanical engineering. Amongst the speakers were Sir Ewart Smith, Mr. T. A. Crowe and Major-General S. W. Joslin. The urgent need to increase the number of technologists within industry was stressed, with its implication that more boys and particularly more of the more intelligent boys should be encouraged by school-masters to take up engineering as a profession. We reprint below the remarks of Major-General Joslin.

The Place of Design and Development

ENGINEERING design and development are processes which go hand-in-hand and which translate the ideas of the scientist into the facts of the workshop. The design engineer takes the theories and the scientific data provided by the mathematician, the physicist, the chemist, the metallurgist, and by the application of engineering practice turns them into working pieces of machinery. His first design will probably have weaknesses. It may not work at all. But it is capable of development and improvement, and by an alternating process of design, development, redesign and further development, the design engineer ultimately evolves a machine or a plant which successfully achieves the performance required. The design which is evolved is passed on to the workshop or production engineer for manufacture, and it is his task to solve the problems of casting, fabricating, machining, fitting and assembly of the parts to make the final article. The design engineer occupies a place, therefore, between the scientist or inventor and the production engineer. It is a key position in the chain of events which may start with a new scientific discovery and end with the commissioning of a power station, an oil refinery or a chemical plant. By many his position will be regarded as the peak of the profession.

The Nature of Design and Development Work

Design work is essentially progressive. There is a constant stream of new scientific discoveries, some of them fundamental and some of them developments of earlier work. These discoveries may arise from an immediate need or they may be items of basic research which have no obvious immediate application and which may remain unused for many years. When a new requirement arises the files are examined and scientific information on the subject explored, further research work being undertaken as necessary. These new discoveries are of many sorts. They may be new metals such as those required to meet the ever-increasing temperatures and pressures of modern power plants. They may be new materials such as the wide range of plastics, new applications of which one sees every day. They may be new physical processes such as nuclear fission. They may be new techniques of manufacture which call for a redesign of objects previously made by more costly and more laborious methods. It is for the design engineer to apply these new discoveries to his requirements.

The basic research work is essentially scientific and done by scientists. The application of this science is engineering and is done by the engineering designer. The distinction is important, since both call for early scientific training, and there is a danger that the young aspirant at school, taught by science masters who are essentially scientists, may be guided into the channel of pure research work or academic science, whilst his aptitudes may lend themselves more to the practical application of scientific ideas.

Design work is not limited to the drawing board. Draughtsmanship is one of the tools of design and the young engineer will need to acquire a knowledge of the conventions of engineering drawing and a reasonable facility for draughtsmanship, but a much more valuable gift is that of sketching free-hand, so that he can demonstrate his ideas to others in an intelligible form. Quite apart from this, the design engineer will take part in experimental work, he will stage trials, he will be vitally concerned with economics, that is the cost of the articles he designs and their working efficiency. He will be referred to if production difficulties arise during the manufacture of his design He will be interested in the commissioning and operation of the equipment he has designed. Design, therefore, covers the whole gamut of operations from first to last in the evolution of a piece of engineering plant.

Engineering design is rarely the work of one man. Whilst there are, of course, individual designers who work on their own and design all the details of a piece of machinery, the great bulk of engineering design work to-day is done in engineering design offices, where the work is broken down into groups and assemblies and components, each the task of a section of engineers and draughtsmen. A master hand probably sketches out the broad design, certainly if the conception is a new one altogether, and continues to control and co-ordinate the work of his team. It is essentially teamwork. A typical design office in a large public authority, which is responsible for the design of a wide range of chemical engineering plants associated with atomic energy projects, is some eighty strong with a chief design engineer controlling about twenty assistant engineers and sixty draughtsmen.

The Qualities Required in a Designer

What are the qualities required in a potential design engineer ? Our object is to determine whether a boy at school, aged sixteen to eighteen, is likely to be a successful engineering designer. It is obvious that he must be interested in engineering, but there are few modern boys who have not at any rate some interest in motor-cars, aeroplanes, wireless and television, even if their interests do not range as far as the engineering problems of inter-planetary space travel.

Engineering design is the application of theory to practice. On the academic side, therefore, the potential engineering designer must be capable of assimilating the necessary theoretical knowledge, which, if he is to make a success of life, will approach degree standard. The university entrance standard for an engineering degree is well-known—generally speaking, three subjects are required at advanced level in the General Certificate of Education, pure mathematics, applied mathematics and physics or chemistry, and one at ordinary level. But only a proportion of boys will be up to this standard, and there are other avenues into the engineering profession through the Ordinary and Higher National Certificate schemes which offer good prospects to boys who are slower than the best. Nevertheless, these alternative ways are harder, and to entrants upon them inadequate basic education is a very heavy handicap. I would certainly not advise a boy to go for engineering design unless he had the General Certificate of Education at Ordinary Level in at least four subjects, including mathematics, physics and English.

On the practical side, a boy should be useful with his hands. He will undergo an apprenticeship in the basic engineering processes and although he will not aspire to the standard of craftsmanship which comes only from long years at the bench, nevertheless, the ability to make some sort of show in the workshop will be a valuable asset to him.

As regards general qualities, design is an art and not a science. The potential designer must have imagination and a strong sense of initiative, and indeed a sense of adventure, provided that he can control it. He must be healthy and robust. He will be dealing with scientific research workers on the one hand and production engineers on the other. He will have dealings with technical sales engineers and erection staffs. He must be a "good mixer." In the lower ranks he will generally be serving as a member of a team and in the higher ranks leading a team. He must, therefore, show promise in leadership qualities.

At school I see the potential design engineer as a boy well-grounded in the scientific subjects, exhibiting an interest in the engineering advances of the present day, blessed with good health, and showing powers of initiative and leadership.

The Schooling of the Design Engineer

It seems desirable to enlarge on the subject of academic qualifications and to consider in particular the value of university training for the design engineer. Undoubtedly every boy who can assimilate higher education benefits from a university career, and as in most other professions, university training will give a potential design engineer the better technical equipment, the broader education and the wider knowledge of men which will assist him to reach the higher ranks of the profession. Moreover, the role of the designer is such as to demand the best recruits to the engineering profession, and on the design side a higher proportion of graduates is necessary than in other branches of engineering. Nevertheless, it is a personal view that there is a danger in demanding too high a proportion of our recruits as graduates. The lack of a degree is not an insuperable bar to outstanding success in the field of engineering design. Mention has already been made of the other avenues of advance which lead to corporate membership of the senior engineering institutions and many able design engineers have followed this avenue of approach. Indeed, they are not infrequently the better designers by virtue of their longer and closer acquaintance with the practical aspects of engineering. I would, therefore, plead for more boys of what I might call sub-university standard to be encouraged to join the engineering profession.

It may be of interest to refer again to the design office already mentioned above. An analysis has been made showing the numbers of engineers in this design team in each of three categories : first, those who entered engineering from elementary and junior technical schools,; secondly, those who started from grammar schools, and, thirdly, those who enjoyed a university education. Six of the engineers are in the first category, eleven in the grammar school class and five are university men (including two, however, who obtained an external London degree at the age of twenty-seven). Of the six most senior men, one is in the first category, three (including the leader of the team) in the second, and two in the third. These figures illustrate the proportions of the different types of entry in a design office which has been working largely in a new field and which has achieved a high measure of success. They serve to show that the bulk of the entry is from the grammar school, that relatively few are university trained, but that the university trained man stands a better chance of reaching the higher ranks.

The Training of the Design Engineer

It may be asked in what way does the training of the design engineer differ from that of other engineers. The answer is that this varies with the large industrial firms who run regular apprentice schemes. It can be argued that no specialisation should take place at this stage. It is necessary for all engineers to acquire an adequate knowledge of the basic engineering processes, pattern-making, foundry work, welding, machine-shop practice, boiler-shop methods, fitting, assembly, &c., and it is particularly important that those apprentices who will not spend a great deal of their working life actually in the shops should get the most out of the practical period of their training.

Nevertheless, in most large firms which run a

regular apprenticeship scheme, interviews are arranged with apprentices at suitable intervals during their training and a decision is made perhaps twelve months before the completion of the apprenticeship as to which line the young engineer is to follow. If he is destined to be a design engineer he will probably be given a somewhat increased amount of drawing office experience, together with special experience in the shops and on the test bed of the particular products which are dealt with in the design office to which he will go on completing his apprenticeship. He will probably serve in the drawing office for a period after his apprenticeship, although as has already been mentioned, his work as a junior design engineer will gradually involve him in many other activities.

The Manchester Joint Research Council's report entitled *Industry and Science*, observes that "A draughtsman without practical experience in the shops can be a very expensive member of the staff," and this is even more so in the case of the junior design engineer.

There is one interesting apprenticeship scheme run by an engineering firm with offices in London and main works in Scotland which may be of special interest to this audience. It is called the "London Office Apprentices Training Scheme," and is a five-year apprenticeship scheme designed for boys from technical and grammar schools, starting at the ages of sixteen to eighteen. The first two years are spent in the engineering department of the London office, six months with the erecting department, six months in the estimating department and twelve months in the drawing office. The following three years are spent at the works, where experience is gained in all departments. Part-time education is continued throughout the five years. This scheme has the merit of breaking in the initiate fairly gently, since during his two years in London he can form an impression of what it is all about, and his workshop experience away from home comes rather later when he is more mature and has a better appreciation of the value of that part of his training.

Fields of Opportunity in Design Engineering

The potential design engineer has two main decisions to make. He must first of all decide in which field of engineering his particular interest lies, whether it is civil engineering or mechanical and electrical engineering. If he decides upon the latter, he must still consider the numerous branches of mechanical and electrical engineering—power plants, railway engineering, automobile engineering, aeronautical, shipbuilding, marine, chemical engineering, electronics, &c., and decide in which branch he would like to make a start. He will do well at this stage to consult a practising engineer, since there may well be fields of which there is little public knowledge but which offer particular scope and interest. A case in point is chemical engineering, which covers an extremely wide field and one which is constantly refreshed with new discoveries, but in which the opportunities are not well-known outside the engineering profession.

The second choice to be made is the *milieu* in which he will work. The majority of entrants will go into industrial apprenticeship schemes, but it may be mentioned that there are good apprenticeship schemes in Royal Ordnance Factories and Royal Dockyards, whilst the Armed Services offer attractions in the form of engineering degree courses to entrants into their technical arms. However, these do not generally lead towards design engineering which is the subject of this paper, and for the design engineer, training in industry is probably the best beginning. Once trained, the design engineer has a wide choice of fields of activity, in industry, in the development and design establishments of the Ministry of Supply, with one of the large public corporations such as the British Broadcasting Corporation, the British Electricity Authority or the United Kingdom Atomic Energy Authority, or with a firm of consulting engineers. Here again he would do well to consult a practising engineer.

It is hoped that as a result of this conference and other related activities there will be a closer link between the seekers after knowledge—the boy, his parents and his schoolmasters—and those, such as members of this Institution, who can answer their queries. In fact, it is for consideration whether a special advisory panel might be formed for this purpose by the Institution.

There is no need to enlarge on the future outlook for the design engineer. This century has seen the discovery and development of the internal combustion engine, the aeroplane, the jet engine, wireless, radar, guided missiles, atomic energy. There is still a vast amount of research work going on in all these fields and fresh discoveries are being made every year. The services of the design engineer will be required in ever-increasing measure to give body and form and practicability to these scientific discoveries as they are turned to the service of man.

Stages in Designing and Building a Nuclear Reactor

The picture of what is involved in engineering design work may be clearer if a concrete illustration is taken, and I propose to run briefly through the stages in designing and building a nuclear reactor of the type used for power production as described by Sir Christopher Hinton in his recent Clayton Lecture to this Institution.

The first stage consists of the basic or long-term research and includes the discovery of the basic theories of nuclear fission, mathematical calculations, experimental measurements by physicists, research work by chemists and metallurgists. This work in general has no particular application when it is done, and it is essentially scientific work carried out by scientists.

The second stage is applied research, when a selection is made of a particular reactor scheme and rough ideas are worked out of its size and possible arrangement. At this stage, exponential experiments will probably be carried out by physicists to determine a suitable core size and the geometry of the reactor, suitable lattice arrangements, experiments on shielding, and so on. Consideration will be given to the choice of materials which may involve a good deal of metallurgical research. The processing of the fuel elements, both before irradiation in the reactor and after irradiation will be studied, possible chemical flow-sheets prepared and experiments made by research chemists. At the same time engineering research will be going on to determine the most suitable coolant, research on heat transfer problems, on the development of specific types of pumps and compressors, and so on. This second stage requires the co-operation of scientists and engineers, and no clear-cut division of duties is possible. It is unlikely that the design engineer to be made responsible for the specific project will be brought in until this second stage is well advanced, but it will be necessary for him to understand and appreciate and apply the results of this applied research work to his specific problem.

In the third stage, a detailed design study is made, whilst further development work takes place with more and more direct applications to the problems required to be solved in the specific project which is now taking definite shape. At this stage the designer will be required to make a preliminary estimate of the cost of construction and to prepare a general plan and programme of work. This information is necessary in order to arrive at the cost and timing of the project, details of which are now submitted to the appropriate approving authority.

When approval in principle has been given, the fourth stage of detailed design work begins. This may be apportioned out in a number of ways, depending on the organisation of the department. There will be a chief engineer in charge of the project, with his design office team. In the particular department here envisaged, separate design offices are organised to deal with each main project. In addition, there are permanent design offices which deal with civil engineering construction, power services and chemical engineering. The chief project engineer, having outlined his project, will, therefore, call upon these latter for assistance in their respective fields. The civil engineering design office will deal with the general layout of the site, roads, bridges, drains, water supply, foundations, concrete and steel structures, ordinary buildings, &c. The power services office will deal with the services required on site, electricity, steam, workshops, &c., and will advise on specialist questions such as the design of electrical gear. The chemical design office will design and provide the chemical services required in connection with the project. The main design office will be organised in sections to deal with the various parts of the project, for instance, the main reactor vessels, the heat exchangers, the turbine house equipment. At this stage, preliminary enquiries will be made from engineering firms and contractors as to suitable items of plant and the capacity of firms to make them. Detailed specifications and drawings will be prepared, detailed programmes for manufacture and erection and detailed estimates of cost will be made. All these are the primary responsibility of the design or project engineer.

At a suitable time, the supply department will be brought in and competitive tenders invited for the various items of plant. The role of the design engineer here is to make his technical requirements perfectly clear, to advise on technical queries arising from the enquiries of contractors and to make recommendations on the tenders received. This will involve detailed examination of tenders and frequently discussions with the firms tendering. After orders have been placed, the design engineer must be prepared to reply to queries on specifications and drawings, to consider suggestions for alternative methods of manufacture, and generally, assisted by an inspection and progress organisation, to ensure that the plant is in accordance with the engineering requirements.

The fifth stage is erection at site and although the detailed supervision of the constructional and erection work is the responsibility of a site engineer, nevertheless, ultimate responsibility for the control of the work and its completion within the approved time and at the approved estimate of cost lies with the design or project engineer and his design office staff. Again, there will be unforeseen difficulties in erection, queries about components and innumerable points on which the guidance of the design engineer is necessary.

The final stage is the commissioning and loading up of the reactor, and again here there are likely to be minor difficulties and hitches which require the intervention or advice of the design engineer. In fact, he will be a lucky man if he is not subjected to a stream of enquiries, requests for advice and general assistance with teething troubles, as well as the redesign of certain items when a few months' operational experience indicates that improvements can be made leading to increased efficiency or greater ease of working.

It will be seen that the design engineer carries the major responsibility for the project from its inception and its final completion. He is involved in a multitude of considerations, not only on matters of engineering design in its narrow sense, but on manufacturing and constructional costs, completion to programmed dates and satisfactory commissioning. He has the final satisfaction of all true artists of seeing the creature of his brain in solid practical form.

Adventure

A much respected past president of this Institution took the title of "Adventure" for his presidential address,* and in conclusion I would like to quote his words. He said: "There is one outstanding quality that distinguishes our profession from many others and gives it unfailing freshness and vitality. There is always something new to be done, some novel process to build up on the foundations laid bare by those who wrest the secrets from nature, the physicists, the chemists, and the metallurgists. We may be glad that we need never stand in the position of Alexander the Great, sighing for fresh worlds to conquer. We may always seek adventure in our profession with courage, not the blind courage of unenlightened ignorance, but courage based on that sound and fundamental knowledge which gives power."

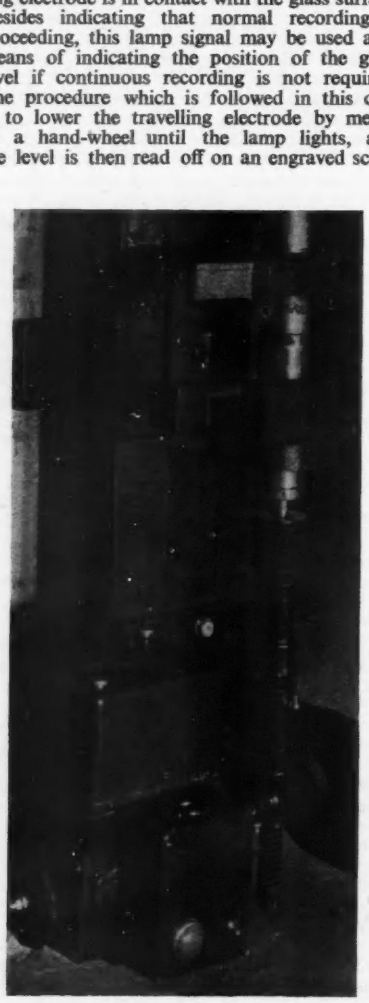
* Presidential Address by Col. A. E. Davidson, D.S.O., A.D.C. *Proc. I. Mech.E.*, October 25, 1935.

Automatic Control of Glass Level in Melting Tanks

IN the manufacture of glassware using a continuous process, the maintenance of a steady level in the glass-melting tank is important if consistency in capacity and weight of finished product is to be attained. Particulars have been received from George Kent, Ltd., of Luton, of a system of level measurement which it is manufacturing in conjunction with the Hartford-Empire Company and which is capable of detecting and recording changes of level of a few thousandths of an inch in a glass melting tank. The equipment is constructed to meet the severe conditions associated with glass manufacture.

The operation of the equipment can be followed with reference to the diagram. A stationary electrode is immersed in the glass in the forehearth of one of the feeders and a travelling electrode is raised and lowered by a motor-driven gearbox. An electrical transmitter geared to the travelling electrode sends signals to the receiver of the recorder, indicating the electrode's position. The two electrodes are energised by a low-voltage a.c. supply, so that when the travelling electrode is raised and then lowered to the point where its tip touches the glass surface, the electrical circuit is completed. This energises a time-delay relay, which causes the travelling electrode to be held stationary for a few seconds, while the "Multelec" level recorder mechanism is switched into operation. After the recording has been made, the geared drive is reversed, raising the travelling electrode to the point where it breaks contact with the glass surface. The drive is then immediately reversed once more and the electrode lowered to commence a new cycle.

An indicator lamp lights each time the travelling electrode is in contact with the glass surface. Besides indicating that normal recording is proceeding, this lamp signal may be used as a means of indicating the position of the glass level if continuous recording is not required. The procedure which is followed in this case is to lower the travelling electrode by means of a hand-wheel until the lamp lights, and the level is then read off on an engraved scale.



Motor-driven gearbox of equipment for glass level control in melting tanks

The photograph we reproduce shows the motor-driven gearbox of an installation at the works of Jackson Bros. (Knottingley), Ltd.

The equipment includes an alarm to call attention to a breakdown in the recording cycle, adjustable high and low-level alarm contacts, a magnetically braked motor drive eliminating overdrive of the travelling electrode, and a safety clutch.

Automatic control of glass "metal" level by regulation of the rate of batch charging is effected

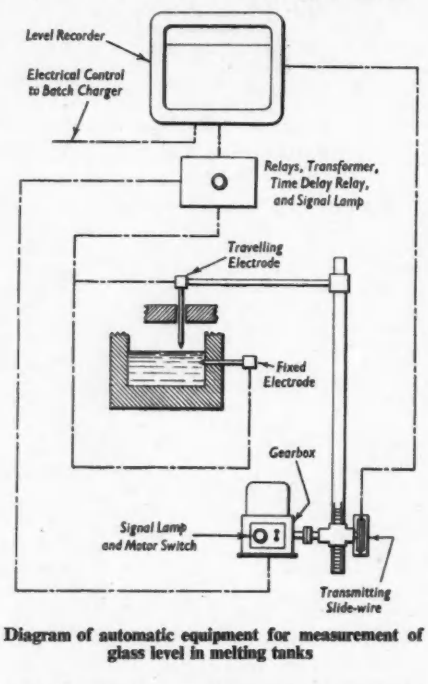


Diagram of automatic equipment for measurement of glass level in melting tanks

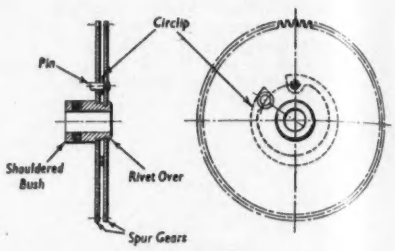
by adding to the recording mechanism already described, a mechanism to vary the rate of charging by the batch chargers. For a continuously running screw charger, in which the speed of rotation of the screw feeding the batch into the furnace is varied, the "Multelec" recorder is fitted with one of the firm's pneumatic controllers. A power cylinder is used to operate the existing speed regulator of the variable-speed driving mechanism. For pusher chargers, which run to a predetermined cycle fixed by electrical timers operating the starters of the charger motors, it is simply necessary to initiate the cycle as often as required to maintain the correct level. For this purpose the "Multelec" is equipped for "on-off" control.

Anti-Backlash Device for Precision Mechanisms

A SIMPLE anti-backlash device for small precision mechanisms which has been devised by the research laboratories of The General Electric Company, Ltd., occupies no more space than the width of an equivalent spur gear. It utilises a standard stock size circlip to provide spring tension to eliminate backlash.

The assembly is made up of two narrow spur gears with a circlip sandwiched between them, as shown in the accompanying drawing. Pins fixed to the wheels pass through the plier holes in the circlip and project through clearance holes in each wheel. This sub-assembly is mounted on a shouldered bush, suitably bored and provided with grub screws for fixing to the drive spindle. One wheel is free to revolve and the other is pushed on and secured by riveting or ring punching against a shoulder. This form of assembly has proved suitable for light drives, but it is pointed out that if the gear is to take appreciable power the bush would have to be splined or knurled to secure the fixed wheel.

The gears are made of thin section material with the necessary holes drilled or punched in position. A pin is riveted to each wheel and the clearance holes should allow for a minimum angular displacement between wheels of approximately two circular pitches. The wheels are



Arrangement of anti-backlash device in which a circlip is inserted between two thin gear wheels to provide tension

similar in shape, but the centre holes are of different diameters, one being a running fit and the other a push fit on the shouldered bush. On assembly with the mating gear the free wheel is tensioned to give an angular displacement of one tooth.

Any standard circlip can be used, but on the smaller diameter gears, where space is restricted, the external form is more suitable. A circlip to give the required tension can usually be selected by trial, but, if necessary, tension can be reduced by grinding the circlip down to a suitable thickness.

We are informed that a drive of this design has been used over a range of wheels from 1in to 3in diameter, but the device is adaptable to a much wider range of wheel sizes. A refinement can be introduced by making the fixed wheel and bush in one piece and turning a projecting ring on it to locate in a recess on the free wheel which is retained on the bush by means of a circlip. A construction such as this obviates any tendency to rocking between wheels, but would only be necessary for high precision work, where extreme accuracy of tooth contact is required.

Biscuit Warehouse with Pallet Handling

A NEW biscuit warehouse which has been built at Southampton for W. and R. Jacob and Co. (Liverpool), Ltd., is stated to be the first warehouse of its kind in this country specially designed for the handling and storage of packed biscuits on pallets. This warehouse was designed and built by C. A. S. (Industrial Developments), Ltd., and covers an area of some 12,000 square feet.

Under the system of operation the parcels of biscuits are delivered by road vehicles at one of two unloading bays on one side of the main warehouse floor. The parcels are taken into the building on roller conveyors and stacked on pallets on which they are transferred by a fork-lift truck to storage areas, and stacked to a height of 17ft. The whole of the opposite side of the warehouse opens on to a loading bay for the vehicles used for local distribution of the biscuits. Eight roller doors, along the side of the warehouse, open into the loading bay and from a sill in front of each door the pallets are unloaded straight into the vehicles. To retain the warmth within the building, long folding doors can be closed along the entrance to the loading bay in inclement weather, and radiant heating panels are set over each of the eight loading doors. A double-glazed roof over the warehouse floor gives good heat insulation in hot weather.

The front of the warehouse is of two-storey construction with the records and administrative offices on the first floor. In addition to the usual amenities for the warehouse staff a large rest room with food heating facilities is provided for the use of the lorry drivers whilst their vehicles are being loaded and unloaded. It is stated that the pallet arrangement of storage and handling which has been introduced enables a 60 per cent saving in labour at this warehouse.

PNEUMATIC TOOLS.—In the article dealing with some of the pneumatic tools and equipment made by the Atlas Diesel Company, Ltd., which appeared in our issue of November 19th, we stated in error that the 8 cwt capacity air hoist was fitted with a positive spring loaded brake. This particular hoist is driven through a worm gear, which renders such a brake unnecessary. The spring-loaded brake actuated by the air supply, as described, is fitted in the firm's heavier capacity M.L.B. series of hoists.

Ventilated Silos for Grain Drying and Storage

At a meeting of the Institution of British Agricultural Engineers in London, on Thursday, December 9th, Mr. C. Culpin, M.I.B.A.E., presented a paper on the drying and storage of grain in ventilated silos or bins on a farm scale. Those parts of Mr. Culpin's paper which are reproduced here deal mainly with fundamental design requirements and practical layouts for silos.

THERE is now available a considerable amount of experimental evidence on resistance to air flow in ventilated silos, and there is no longer any excuse for the bad designs that continue to be executed. One essential requirement of a ventilated silo plant is the transmission through the grain of the maximum quantity of ventilating air with the least possible power requirement. This can only be done if a few elementary rules are observed, one of which is that air ducts must be of ample size. Small-diameter circular metal ducts are generally unsuitable for multi-silo plants because the duct is almost invariably made too small. It is a simple matter to measure the pressure drop along a duct, and examples have been encountered on farms where the pressure drop has been 1in W.G. for every 20ft of duct. This usually means that a silo at the far end of a line cannot be ventilated effectively. Size of the ducting should be such that air speed does not exceed 2000ft per minute, and this is easily arranged if ducts are of masonry.

Floor Resistances.—Many quite effective ventilated silo plants have been based on the use of porous floors made of 2in foamed slag blocks, supported at their corners by bricks on edge. Early experiments had shown that the resistance of such a floor was only about 0·2in W.G. at 10ft per minute, 0·3in W.G. at 15ft per minute, and 0·5in W.G. at 20ft per minute. This kind of floor has, however, been found somewhat unpredictable in practice. Blocks made by different manufacturers vary considerably in resistance to airflow and on some farms where the spaces between blocks were thoroughly pointed (a practice that must be discouraged), resistances have been considerably above this. Moreover, several cases have occurred where the floors have become less permeable after use, due to clogging with dust. In several instances it has been necessary to take up floors and substitute more permeable materials.

Experiments at the National Institute of Agricultural Engineering[1] have shown that it is advisable to test floor resistances with a covering of grain, and comparative experiments were carried out on a number of types of floor, each with a covering of 6in of grain. Results obtained with some of the materials at air speeds of 15ft per minute and 20ft per minute were as follows :

Floor Resistances

	Resistances (in w.g.)			
	At 15ft/min		At 20ft/min	
	Not pointed	Pointed	Not pointed	Pointed
Malt kiln tiles	0·03	0·03	0·03	0·04
Slotted concrete blocks	0·06	0·09	0·10	0·15
2in commercial "Leca" blocks (fine)	0·16	0·25	0·25	0·40
2in commercial foamed slag blocks	0·29	0·63	0·45	Not recorded

If resistances were never higher than those shown by these experiments there would be little to worry about, but in further experiments reported by the Scottish Machinery Testing station, where oats were being dried in full-size silos, the values for foamed slag blocks that were only pointed sufficiently to prevent grain falling through were considerably higher, reaching 0·8in W.G. at an air speed of 20ft per minute. The high resistance was assumed to be due to the settling of the grains of oats into the seams between the blocks. The possible magnitude of the floor resistance problem was revealed by an example where a floor of foamed slag blocks had been pointed much more than is recommended. A pressure drop of 5in through the floor was recorded at an air speed of less than 7ft per minute. Such an example shows that it is necessary to find more reliable materials.

Wedge wire, a material that has replaced kiln tiles in many maltings, has been found an efficient, but a somewhat expensive, floor material if the whole floor area is covered with it. Several plants have therefore been installed with the wedge wire laid in strips, and when this is done it becomes necessary to know what is the maximum permissible width of the intervening strips, which can be of less permeable materials such as foamed slag blocks. Unfortunately, there has not been any accurate experimental work on this point, but experience with commercial plants shows that a width of 9in is not too great for general usage. Clearly, the figure depends on a number of factors, including grain depth and initial moisture content, and it is particularly advisable with such floors to turn the grain once after drying.

A cheaper material that is proving very satisfactory is perforated metal. A type of material that is coming into common use is 16-gauge perforated sheet with forty to fifty $^{5}/_{64}$in holes per square inch. In some cases this is simply laid on bricks on edge, spaced at about 9in centres. A good method is to fix the sheets to 1½in square wooden frames which rest on bricks laid flat, the middles of the sheets being supported by bricks on edge. This makes it easy to handle the sheets and to remove them when necessary. A triangular wooden fillet round the edge makes a good finish. The resistance of such a material, like that of wedge wire and kiln tiles, is negligible at all practical air speeds. Another method of distributing the air in vertical-flow ventilated silos is by means of a system of inverted troughs standing on supporting legs on a plain floor. These may conveniently be of triangular or U-shape, and may be constructed of metal or wood. Little is known at present concerning design requirements for this method of air distribution. As a general guide, it seems likely that the width of the ducts and of the spaces between them should not exceed about 1ft, while the height from floor to the underside of the inverted troughs should not be less than one-twelfth the distance between duct centres.

One of the disadvantages of the simple inverted duct method of distribution is that above a certain air speed the grain is carried along the duct by the air stream, and the ducts fill up with grain at the far end. This can make distribution very uneven, or prevent effective ventilation altogether. Moreover, this fault is not readily detected, nor easily rectified, because of the situation of the ducts beneath the mass of grain. The trouble can, of course, be prevented by covering the apertures with perforated metal, but this makes the method of construction expensive. A method employing portable metal ducting can be employed for drying grain on any suitable barn floor.

Fundamental Design Requirements

Design requirements for ventilated silos must be based partly on experimental results and partly on assessment of the needs of the particular farm. Apart from size of plant, the following are the chief factors concerned :—Average moisture content of the grain to be dried and stored ; the weather at the time of drying; marketing needs and policy which determine such matters as the maximum length of drying period that can be considered, and the extent to which the plant must handle more corn than can be stored at any one time in its silos. None of these factors is absolute, so there is room for a fairly large measure of difference of opinion on minimum requirements.

The speed of drying is a vital design factor, but there is, unfortunately, little information from controlled experiments to show just how slowly grain of various sorts and conditions can be dried in a ventilated silo installation before it has its value reduced through the development of mustiness. Practically all the information available comes from observing farm plants, and from such observations the following facts emerge :—(1) Troubles from the development of mustiness or of heating have been rare, but most instances are caused by a design of plant that makes it impossible to ventilate a sufficient number of silos, and results in damp grain being left completely unventilated for periods of twenty-four hours or more. (2) A less frequent source of trouble, but one which has occurred on several plants once and once only, is a result of inexperience on the part of the operator. Ventilation has sometimes been suspended, in order to save cost, or for other reasons, long before the grain was dried throughout ; this mistake is seldom repeated. (3) If a farmer understands the drying process, has the necessary moisture testing equipment, and is able to blow 10ft per minute of warm air through two-thirds of the silos simultaneously, he may suffer some inconvenience through a too-slow rate of drying, but he is seldom in any real danger of damaging the grain. (4) The factor that really determines the necessary drying capacity and calls for a fairly high drying rate is what may be simply called the "management requirement." Many ventilated silo installations must be able to dry, when necessary, double the amount of corn that can be stored in the silos at any one time. This means that it must be possible in any season to dry full silos (at 10ft depth) in an average period of about fourteen days ; and it is this factor, rather than any other, that makes it advisable to specify a drying rate of the order of ½ per cent per day from at least one full silo, and a rate not far short of ¼ per cent per day when two-thirds of the silos are full and being blown simultaneously.

We must now see what rate of airflow is required to achieve this. The calculation is easily understood by considering only a vertical column of grain, 10ft deep, standing on a base having an area of 1 square foot. This column will contain about $10 \times 50 = 500$ lb barley, and removal of ½ per cent moisture daily means that approximately 2½ lb of water has to be driven off in twenty-four hours. The air supply required to achieve this is therefore $12{,}000 \times 2\frac{1}{2} = 30{,}000$ cubic feet per day, or $30{,}000/24 \times 60 = 21$ cubic feet per minute per square foot of floor area.

The combined resistance of duct, floor and grain at this air speed is likely to vary from about 4·5in to 6·5in W.G. according to nature of crop, silo floor, and other factors. The next important question to decide is how many silos it must be possible to ventilate at this high rate, and what performance is required at some slightly slower air speed through full silos. This leads us to consider what is practicable as well as what is desirable, and necessitates a study of the fan characteristics.

The paddle-blade fan, if correctly chosen and driven at a suitable speed, has a performance that matches well the very variable requirements of a typical multi-silo farm plant, where it may be necessary to ventilate simultaneously from one to six or more full silos. As the number of silos ventilated increases, the amount of air delivered to each falls relatively slowly. Thus, when ventilating a single 10ft square silo the air speed will be $2200/100 = 22$ft per minute and the resistance is 5·9in W.G. If two silos are ventilated, each receives $4200/200 = 21$ft per minute, while when six full silos are ventilated the performance will be $8600/600 = 14$ft per minute through each silo, against a resistance of 3·3in W.G. Average rate of moisture removal from the six full silos will be ¼ per cent per day. The horsepower required increases progressively with increasing air volume, and with this type of fan power requirement rather than fan capacity is what limits maximum air volume. Care must be taken in operation not to overload the power unit by such practices as blowing a very large number of empty or almost empty silos, but if this risk is appreciated, this type of fan can hardly be bettered for large installations. If it is well balanced and sturdily constructed, with a stiff shaft, sound bearings of ample dimensions, and a rugged frame, it should run for many years without needing any replacement parts. A moderate level of efficiency is satisfactory, since any inefficiency merely serves to warm the ventilating air.

With the dual-stage, axial-flow fans, the volume resistance curve is steeper and the fan is non-overloading, the horsepower falling off at maximum volume. This kind of fan is convenient to install, but the method of construction, with the fans mounted directly on the motor shafts, makes maintenance rather more difficult than where a separate motor is employed.

Whatever type of fan is used it is necessary to arrange an unimpeded dust-free inlet, and where the fan blows directly into a large passage,

a transformer box with slides having an angle not greater than 7½ deg. should be employed where practicable.

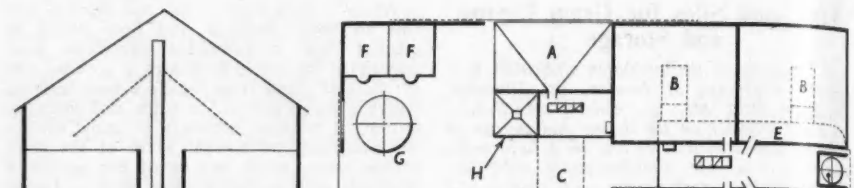
Heating the Air.—There are three main methods of heating the air to reduce its average relative humidity to the required 60 per cent, viz. by the use of electric heaters, by means of an oil-fired burner, and by using waste heat from the internal combustion engine that drives the fan. A fourth method of reducing the relative humidity is by the use of a chemical dehydrating agent such as silica gel.

The first method is simple, and the required heater capacity may be roughly calculated on the basis of 3kW of heater elements for every 1000 cubic feet per minute delivered by the fan when ventilating at maximum volumes. This will provide for a temperature rise of approximately 10 deg. Fah. at this volume. In exceptionally bad circumstances of climate it may be desirable to install 4kW per 1000 cubic feet per minute at maximum volume, but use of this amount is only necessary in very cold foggy weather in areas where harvests are often late. In more favourable climates and where harvest is invariably early, some reduction in the heater capacity is possible, and no more than 2kW per 1000 cubic feet per minute maximum is called for. It is usually possible to arrange some makeshift auxiliary heating for exceptional conditions, and such devices as an anthracite brazier were put to good use near the fan inlet during last harvest. There must, of course, be adequate switching arrangements for the heater elements so that the load can be adjusted to suit the weather and the quantity of air being blown.

Experience on farms has shown that metal-sheathed heater elements are preferable to bare wires mounted on porcelain. They are much more robust and more easily cleaned, and for these reasons they require less frequent replacement. Moreover, the sheathed elements take up less space, and can be more easily shaped so as to avoid any appreciable restriction of air flow.

A small oil burner that will burn efficiently without smoke can be employed for almost any size of plant, but is usually only chosen for large plants, where the saving in cost compared with use of electricity is appreciable. Total electricity consumption for both fan and heater unit in all-electric plants only averages about 15 to 20 units per ton of grain for 1 per cent moisture extraction, and for most small plants the extra convenience and safety of all-electric operation is so important a factor as to outweigh any theoretical saving from the use of either an oil-fired burner or the method of using engine waste heat.

The latter method has been proved quite sound in practice on many farms, while an N.I.A.E. study[2] gives the results of some theoretical calculations and of a trial with a small 5 h.p. air-cooled diesel engine. This latter study showed that when arrangements were made to collect, by the use of simple devices, as much as possible of the waste heat from the exhaust and cooling systems, a temperature rise of up to 15 deg. Fah. could be fairly readily obtained with an airflow of 3500 cubic feet per minute. The required range being only 6 deg. to 10 deg. Fah. rise, it was necessary to dispense with the home-made heat exchanger that had been rigged up to collect waste heat from the exhaust gases, and arrange a door so as to bleed in some cold air. In practice, it is usually fairly easy to secure an adequate temperature rise when a tractor operating on vaporising oil is used to drive the fan, but it is not easy to secure enough heat from an efficient tank-cooled diesel engine, unless the latter is also used for auxiliary drives. On the other hand, where a tractor or radiator-cooled engine drives conveying equipment as well as the ventilating fan, it is essential to provide an adjustable cold-air bleed to avoid raising the temperature of the ventilating air too high. Where electricity is not available this method of warming the air can be thoroughly recommended, but I personally do not advocate it where electricity is available in suitable quantity. The engine usually needs to run for almost twenty-four hours a day, or round about 1000 hours a year. This means a considerable amount of attention to its maintenance, the possibility of mechanical troubles, and the certainty that an overhaul will be needed most years.



A—Grain intake hopper. *B*—Branch duct. *C*—Cleaner. *D*—Fan. *E*—Main duct. *F*—Meal bins. *G*—Mixer. *H*—Hopper feeding mill. *J*—Silos.

Recommended layout of four-silo plant of 100 tons capacity

Some Practical Layouts

One of the difficulties that has hindered wider adoption of the ventilated silo system has been the lack of standardisation caused by the use of a great variety of shapes and sizes of silos, and by the great variety of materials used to construct them. A big market may still await a firm that can produce at a reasonable price an attractive complete prefabricated plant, based on the design requirements already discussed, and with the necessary adjuncts such as cleaning and conveying equipment incorporated. Such units would, of course, have to be made in more than one size; but the needs of most farms would be covered by sizes ranging from 50 to 300 tons capacity. In the meantime, design of each installation is a separate job, but it may be helpful to show some layouts that have the merit of simplicity, and may provide a few useful ideas.

The building of the silos themselves, and the construction of the necessary ducting, are factors of prime importance in securing an efficient and economic installation. On many farms, the work may be satisfactorily done by farm workers. The silos may be round or rectangular, according to the circumstances on the site and the materials of construction; but, in general, rectangular silos are preferred for indoors, while the circular pattern may be cheapest for outdoor use. Where the silos are built of materials such as bricks or concrete blocks, the necessary reinforcement must be carefully studied. There are now available efficient rectangular metal silos which are easy to erect. In one design, the roof may be carried on the channel iron stanchions at the corners of the silos, and the nest of silos is also rigid enough to support any well-designed conveyor. There is no reason to suppose that metal silos are unsuitable for ventilated grain stores, and there is little reason to expect a short life of those silos which are soundly constructed and protected from corrosion.

The simplest layout of all is obtained with the use of portable ventilating and conveying equipment. The silos may then be sited in any accessible place, and the conveying or ventilating equipment moved up as required. Most plants with more than two silos that start off like this eventually have a more or less fixed system for both ventilating and conveying. Such plants sometimes receive much publicity in the early days on account of their low capital cost per ton of grain stored. A second visit after a few years often shows that the advantages of having a cleaner in the system and of being able to ventilate effectively have become appreciated as a result of experience. Nevertheless, for a small farm there is nothing fundamentally unsound in a three-silo plant that is able to ventilate effectively two full silos at a time, and such a plant can often get along quite well with combined portable ventilating and conveying equipment. For 100 tons capacity a compact layout such as that shown diagrammatically herewith may be convenient. The two bucket elevators will handle the grain through the cleaner, to and from the silos, and also to the milling equipment, while the ventilating equipment is simple. One of the most satisfactory types of air control door for any plant having a ventilating tunnel like that illustrated is a door with loose-fitting hook hinges which fit on to pins attached to an angle-iron frame that is let into the branch duct. The door is set at an angle so that it always tends to close itself when the wire connected to it is released. This wire passes through a piece of suitably bent conduit and is attached to a hook when the air door is opened. Either the door itself or the frame on which it seats carries a soft rubber moulding to give an airtight seal. Good control doors are a very important part of any plant. Some plants have been encountered where the amount of air escaping through a number of badly fitting air valves was greater than the amount passing through the silo that the farmer was trying to ventilate.

For most plants of up to about 250 tons capacity it is no great disadvantage if the lower conveyor passage and the main ventilating duct are combined. There is no limitation on ventilation during the daytime hours when the upper conveyor is filling a silo, and the infrequent use of the lower conveyor for emptying a silo can be arranged in wet weather when shutting off ventilation for a short period is least likely to be a disadvantage. With a man in attendance it is possible with such a plant to arrange simultaneous ventilation and use of the lower conveyor; but with large plants it is essential that there should be nothing to prevent constant unattended ventilation of as many silos as may be necessary, and this requires a separate main duct that is not used for conveying. Where the operator can easily walk inside the main duct, a simple and efficient air door consists of a hardboard sheet, with a strip of soft rubber round the edges, which is fixed by a pair of simple wooden turn-buttons into a well-made angle-iron frame.

Almost all farm installations require a grain-receiving hopper, a grain cleaner, and equipment for conveying the grain between these devices and the silos, or from one silo to another. The provision of equipment that gives complete flexibility is often quite expensive in relation to the cost of the essential silos and ventilating equipment, and it is certain that many existing farm plants would have been better if a little more attention had been paid to ventilation and a little less money spent on conveying. Nevertheless, a good handling and cleaning system is essential to most medium-sized and large plants, and the potential labour-saving factor of the ventilated silo system is one of its important attributes.

The chief difficulty with grain intake hoppers is the fact that country builders generally seem to be no more capable than farmers of overcoming the difficulties of a high water table. Most builders seem to have little idea how to set about the job of making the elevator pits watertight. Many farmers make the problem unnecessarily difficult by insisting on large-capacity intake hoppers: this should be quite unnecessary with a ventilated silo plant if cleaning and conveying equipment are sensibly chosen. In any case, where trouble is likely it is preferable to

build a small receiving hopper and an elevated storage bin if this is necessary.

In the early days of ventilated silos, pneumatic conveying equipment was almost invariably used. While it had many advantages, and is still often invaluable for difficult layouts and in conjunction with waste heat plants, the disadvantages of high power requirement and dustiness have proved serious, and most farmers to-day prefer to install mechanical conveyors of one sort or another. Oscillating conveyors have proved very satisfactory for horizontal runs where they are well made and well installed. During the 1954 harvest an unusual amount of difficulty has been experienced in securing uniform ventilation of silos, due to extra packing of the corn where it falls into the bin from, or is blown into the bin by, the conveyor. Remedies are to use a spreading device, or to spread by hand, without trampling on the grain, at fairly frequent intervals during filling. Ventilation may also be seriously interfered with if grain that is not reasonably clean is put into the silo. Contaminants tend to collect in patches that are relatively impermeable, and since these patches often contain greenstuff that is likely to heat if not properly ventilated, they are a potential source of serious trouble. The remedy is undoubtedly to clean adequately all grain that needs such attention before putting it in the silos. Introduction of a cleaner requires attention to a small detail of planning that is often overlooked in the early stages, viz. the provision of some suitable means of collecting the blowings.

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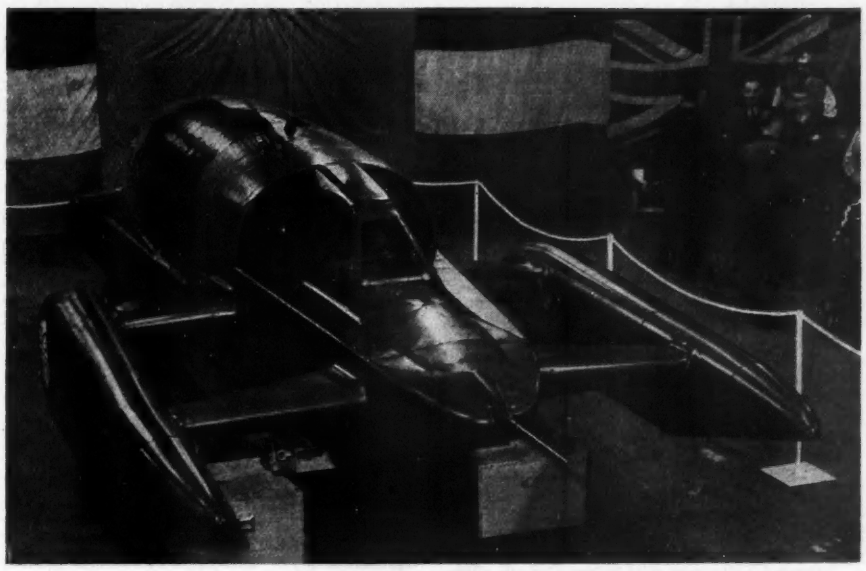
Turbo-Jet Hydroplane

AT present at Ullswater awaiting suitable weather and water conditions is the turbo-jet hydroplane "Bluebird," which has been built by Samlesbury Engineering, Ltd., to the designs of Norris Bros., Ltd., for Mr. Donald Campbell's forthcoming attempt on the world's water speed record. Since 1903, when Mr. S. F. Edge attained 19·53 m.p.h., the speed has been raised gradually to 57·495 m.p.h. in 1914, then to 98·76 m.p.h. by the late Sir Henry Segrave, and to over 100 m.p.h. in 1931 by Gar Wood in one of the "Miss Americas." The late Sir Malcolm Campbell raised the record to 141·74 m.p.h. in 1939, and in 1950 Mr. S. S. Sayers, of the U.S.A., achieved a speed of 160·32 m.p.h., which he raised to 178·497 m.p.h., the existing world's record, in the following year.

The present project has been under way for two years and due consideration has been given to the disaster which overtook Mr. John Cobb when travelling at about 200 m.p.h. There was a similar occurrence in Italy recently when another record attempt ended in the boat disintegrating at about the same speed. Both disasters emphasised that with hulls travelling at such high speeds unknown stresses of considerable magnitude were set up and suggested the existence of a "water barrier." This "barrier" represents the pressures generated between the planing surfaces and the water and can, we understand, create a pitching cycle of high frequency and amplitude, which may cause a sudden disintegration of the hull structure. To meet this problem a new form of structure has been evolved and the new craft incorporates in its design the results of wind tunnel and towing tank experiments with self-propelled models.

The hydroplane has an overall length of 26ft 4¾in, a maximum beam of 10ft 6in, an overall height of 4ft 8½in, floats 12ft 3¾in long, and an all-up weight of approximately 2½ tons. It is of all-metal construction, combining great strength with light weight, in which a hull of "Birmabright" light alloy is built around a main frame of high-tensile tubular steel. This inner framework, a short account of which appeared in THE ENGINEER of July 30th, is of chrome-molybdenum seamless tubing of square section, to which fabricated frames, of light alloy and shaped to follow the hull form, are riveted. Special rivets fasten the outer skins to the frames and watertightness is ensured by the use of welding and sealing compounds. To withstand the high stresses set up in the flat underside of the hydroplane at high speeds, the bottom construction consists of light alloy sheets riveted to a corrugated metal base. There are two main spars, which are independent units passing right through the hull, consisting of a main framework, of light alloy, built up to form a strong box girder. To the underside of the floats, which are of similar construction to the spars and fastened to them are attached the main planing shoes, machined from solid light alloy billets. These shoes, together with the rear wedge of the main hull, form the actual three-point planing surfaces.



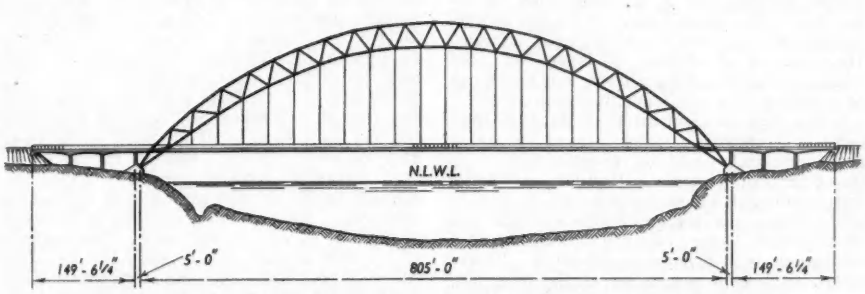
The turbo-jet hydroplane "Bluebird"

A Metropolitan-Vickers "Beryl" turbo-jet aircraft engine of straight-through design provides the necessary power and the engine, which is unmodified except for the removal of altitude control gear, has a ten-stage axial compressor and a single-stage turbine and delivers a static thrust at sea level of 4000 lb at 8000 r.p.m. for a weight of 1780 lb. The power unit measures 11ft 9in in length by 3ft 0½in in diameter, and has a consumption of 650 gallons of kerosene per hour and 3 tons of air per minute, the fuel being stored in a saddle tank. Special attention has been paid to the deflection of surface water and electrically-operated flaps have been mounted on each side of the cockpit to prevent the entry of water into the engine air intakes when the craft is moving at low speed.

Proving trials are expected to take some considerable time and will involve technical research to check experimental model results. For this purpose new electronic instruments have been developed and fitted which will accurately record the forces acting upon the hull and telemeter by radio an indication of these forces to a shore station. Should these stresses rise to a dangerously high level provision has been made to give audible warning of this to the pilot. Provided that the preliminary trials are completed satisfactorily, Mr. Campbell will be able to make an attempt on the record, to gain which "Bluebird" must achieve a mean speed, of two runs, one in either direction, of the existing record multiplied by a factor of 1·0075.

Bridge Across the River Volta

THE Government of the Gold Coast has accepted a tender for a single-span steel bridge and approaches to be built across the river Volta, at a cost of approximately £750,000. The bridge is situated at Adomi, 2½ miles north of Senchi, and will carry two lanes of traffic on a 22ft wide roadway. It will have short reinforced concrete approaches and about 5½ miles of new approach roads which are included in the contract. The main arch span is shown in the accompanying diagram; it will be 805ft long and 38ft wide. The arch ribs will be made of high-tensile steel and the arch will have a rise of approximately 173ft. The total weight of steel involved in the contract is approximately 1200 tons and it is anticipated that the bridge will be completed, ready for traffic, during the early part of 1956. The river is at present crossed by a ferry which handles well over 200 road transport vehicles a day. The consulting engineers are Sir William Halcrow and Partners, and Freeman, Fox and Partners, and the successful tenderer for the contract was Dorman Long (Bridge and Engineering), Ltd.



Elevation of proposed bridge and approaches across the Volta River at Adomi, Gold Coast

ZINC ALLOY DIE CASTING BULLETIN.—The first English edition of a new series of European bulletins on zinc alloy die casting has just been issued by the Zinc Alloy Die Casters Association. For the production of this new periodical the Zinc Development Association, the Commission Technique des Alliages de Zinc, the Zinkberatung and the Montevecchio Company will work in close collaboration. These bodies will prepare successive identical issues for wide circulation in English, French, German and Italian. The first number is devoted to the use of zinc alloy die castings in the European automobile industry, and subsequent issues will deal with other fields of application. The bulletins will be sent free on request to those who are interested upon application to the Association's offices at Lincoln House, Turl Street, Oxford.

National Metal Congress and Exposition

BY OUR AMERICAN EDITOR

THE 36th National Metal Congress and Exposition was held in Chicago, Illinois, from November 1st to 5th. As in previous years, it was sponsored by the American Society for Metals, the American Welding Society, the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers, and the Society for Non-Destructive Testing. Some 450 companies engaged in either the production, treatment or fabrication of metals gave displays and demonstrations of their products or services at the exhibition, which was held at the Chicago International Ampitheatre. Over the years, the Metal Show has continued to become ever broader in its coverage of the metals and metal working field, and gone are the days when it was concerned mainly with the heat-treatment of steels. This year there was again a strong accent on the fabrication and application of some of the more recently developed metals such as titanium zirconium, magnesium and tantalum. Furthermore, there was a noticeable trend toward the display of vacuum melting furnaces and of vacuum-cast metals.

An indication of the great strides which have been made in titanium production was presented at the exhibition in the form of a 4000 lb coil of 50in wide, commercially pure titanium sheet which had been rolled on a hot strip mill at a speed of 1200ft per minute. A wide variety of titanium and titanium alloy components was also exhibited on the stand of the Mallory-Sharon Titanium Corporation, of Niles, Ohio. Of particular interest is this firm's new double-melted ternary titanium alloy " MST 3 Al-5Cr," which contains 3 per cent aluminium, 5 per cent chromium and less than 0·1 per cent carbon. The alloy has been developed primarily for bar and forging applications and has good creep resistance and high strength properties both at room and elevated temperatures. The low carbon content and a complete alloy homogeneity are obtained as a result of the new double-melting process used in making this analysis. The material is available in billet, bar, rod, forging, extrusion or plate form, and plates can be supplied to a minimum thickness of $\frac{1}{4}$in.

Initial tests on small ingots of the alloy indicated that ultimate strengths up to 165,000 lb per square inch could be obtained with more than 6 per cent elongation. However, experience with production ingots weighing up to 2000 lb now indicates that the predictable strengths will be somewhat lower than this value, but that elongations will increase considerably. Representative physical properties of the alloy are listed in the following table :—

Physical Properties of Titanium Alloy "MST 3Al-5Cr"

Ultimate tensile strength	155,000 lb per square inch
0·2 per cent offset yield strength	145,000 lb per square inch
Elongation in 2in	13·5 per cent
Reduction of area	40 per cent
Modulus of elasticity	$16·7 \times 10^6$ lb per square inch

At present no practical method of improving the strength levels is known without reducing the ductility to very low levels. It is therefore felt that the best condition for the alloy is developed by controlling the forging procedure and using the as-forged properties. The recommended temperature range for forging and rolling is 1850 deg. Fah. maximum and 1400 deg. Fah. minimum. It has been found that if the material is allowed to cool to much below 1000 deg. Fah. in the dies, brittleness may result, with no certainty of restoring ductility, particularly in thin sections. It is permissible to heat the material more in closed die drop forging if the time in the furnace is reduced to the absolute minimum. Final reduction should take place between 1400 deg. and 1600 deg. Fah. to ensure some work in the two-phase (alpha-beta) field.

Since all alloys containing both alpha (aluminium) and beta (chromium) stabilisers are prone to be relatively unstable thermally, experiments have been completed which indicate the degree of instability which occurs in the Al-Cr alloy. In these experiments sample bars were heated for the times and at the temperatures indicated, air cooled to room temperature and then machined and tested. The results are indicated in the following table :—

Thermal Stability of "MST 3Al-5Cr Alloy"

	Ultimate tensile strength, lb per sq in	Yield strength, lb per sq in	Elongation, per cent	Reduction of area, per cent
As forged...	134,910	127,210	12	24
752 deg. Fah. for 142 hours, air-cooled	145,000	121,000	6	12
932 deg. Fah. for 21 hours, air-cooled	139,000	124,000	6	6
1112 deg. Fah. for 24 hours, air-cooled	125,500	109,000	3	4

The test bars were taken from a 6in square forged bar, which accounts for the low physical properties. This approximates the size of present engine components such as turbine wheels, which would be subjected to the temperatures used in the experiments. It can be seen that 700 deg. Fah, would be a safe limiting temperature for the alloy. The gradual embrittlement of the alloy is the result of compound ($Ti\text{-}Cr_3$) precipitation, which is believed to be titanium decomposing into alpha and $Ti\text{-}Cr_2$. Welding of the alloy suffers from the same drawbacks as all titanium alloys containing both alpha and beta stabilisers. However, recent work indicates that welds having parent metal strength and ductility can be made.

The initial public display of a new die steel, known as " Ottawa 60," took place at the stand of the Allegheny Ludlum Steel Corporation, of Pittsburgh, Pennsylvania. The material is a high-carbon high-vanadium steel which has been specifically designed to deep draw and form stainless steel without " pick-up " or galling and to give " the ultimate " in wear resistance for this application. This steel is composed of many hard, abrasion-resistant vanadium carbides dispersed uniformly throughout a hard matrix when heat-treated. " Ottawa 60 " can be machined and cut by conventional methods, other than hack or band sawing. Because of the many hard vanadium carbides present, it does not machine as well as high carbon, high chromium tool steels. The material is available in the form of forgings as well as bar stock. The analysis of the steel is such that in the hardened condition it provides optimum wear resistance, requiring extreme care to be used in grinding. The use of aluminium oxide wheels, or diamond wheels, is recommended. In polishing, diamond dust has been found to work very satisfactorily. It is believed that the use of techniques developed in grinding sintered tungsten carbides will ensure proper results. The steel has an analysis of 3·25 per cent carbon, 1·00 per cent chromium, 1·00 per cent molybdenum, and 12·00 per cent vanadium ; 1750 deg. to 1800 deg. Fah. is the best hardening range for both open fire and pack hardening of the steel and should result in a hardness of Rockwell C64 to 66.

Sintered tungsten carbides are continuing to find applications in the field of rolling mills, and several interesting solid carbide rolls were displayed by the Carboloy Department of the General Electric Company, Detroit, Michigan. According to the firm, a pair of solid carbide Sendzimir strip mill work rolls have led to a higher quality of strip surface finish and have established new production records for a major American producer of stainless steel strip. The rolls are 19in long by 1·290in O.D. and were fabricated from grade 55 A Carboloy cemented carbide. The material rolled in this particular case is the A.I.S.I. " 430 " stainless steel. The strip widths are 16in and 14in, and the starting thickness is 0·060in and 0·078in. The strip is reduced to 0·028in and 0·025in, respectively in four to six passes. The carbide rolls are used for either the last finishing pass or the last two passes as an exceptionally bright surface finish is required since the material is used principally for automotive and household appliance trim. The reduction in thickness of strip per pass averages 20 per cent and the rolls are operated at 200ft per minute. The roll temperature while running is approximately 120 deg. Fah. and the temperature of the strip is about 150 deg. Fah. It has been found that while high-speed steel rolls on the same operation last for about one coil before surface finish on the strip begins to deteriorate, the carbide rolls have run for a minimum of four coils with no signs of inferior surface finish becoming evident. The roll surfaces of both the steel and the carbide rolls have a similar appearance before being put into service.

The considerable progress which has been made in the field of magnesium sheet production due to the installation of a modern strip mill by the Dow Chemical Company, of Midland, Michigan, was illustrated at the Metal Show by the display of a 2000 lb coil of 0·096in thick by 48in wide coil of magnesium sheet. It is of interest to note that at this particular gauge and at heavier gauges, magnesium is now competitive with aluminium sheet on the American market.

In the field of welding one continues to note the trend away from motor generator sets, and most manufacturers now tend to concentrate on a line of a.c. transformer and d.c. rectifier welding sets. A representative range of such equipment was demonstrated on the stand of the General Electric Company, of Schenectady, New York. The a.c. transformer sets are now made in three basic sizes, with respective outputs of 300A, 400A and 500A at 40V. Stepless current control is obtained by using a moving-primary-coil design, in conjunction with a large current scale expanded in the lower ranges. The current output is determined by the space created between the primary and secondary coils when the primary coil is moved up or down its finely threaded shaft. The three models have current control ranges of 35A to 400A, 52A to 500A and 65A to 625A, respectively. A good arc stability at even the range extremes makes it possible to use coated electrodes effectively even at the minimum and maximum settings. An interesting aspect of the new a.c. transformer set is its automatic hot start, which provides for instant arc striking, even in the lower current settings. The hot-start device is self-regulating and requires no manual adjustment. When an electrode makes contact with the work, an extra surge of current is automatically supplied for approximately one-quarter of a second. The arc is struck instantly and the current automatically then returns to normal. In addition to saving time through instant arc striking, the hot-start device gives extra penetration at the start of the weld where it is most needed and reduces the tendency toward " sticking."

The company's d.c. rectifier welding sets are being made in two basic sizes, with respective outputs of 300A and 400A at 40V, and are now being equipped with arc-force control. It is well known that as electrode metal passes from the rod to the base plate, short circuits occur at frequent intervals ; furthermore, the shorter the arc, the more frequent are the short circuits. Without arc-force control, the metal cools during these practically heatless periods, and the electrode often freezes to the weld, or the arc is lost. A skilled operator will instinctively lengthen his arc to avoid " sticking," but with this changing arc length, the quality of the weld deposit is sacrificed. The General Electric arc-force control has been developed to blast away these metal droplets. It permits the use of shorter arcs without freezing of the electrode and thus provides fast welds of good quality. The arc-force control operates continuously, without cutting out in short-circuit conditions. It is claimed to permit welding with shorter arcs than is possible with any other rectifier welder. Its powerful peak surges of short-circuit current blast away the metal bridge, which would otherwise freeze the electrode. This short-circuit

current lasts for only a fraction of a second. Due to the arc-force control the arc is easier to handle, the deposition rates are increased, and the penetration is deeper. These conditions are particularly valuable in first or root passes in pipe and groove welding, in vertical welding and in overhead welding.

The Arc Welding Department of the Westinghouse Electric Corporation, Buffalo, New York, has developed a new consumable-electrode, shielded inert-gas arc welding process which received its initial public demonstration at the Metal Show. The field tests which have been conducted by the firm indicate that the process results in a 15 to 20 per cent faster welding speed at a 25 to 50 per cent reduction in costs over other manual and semi-automatic inert-gas arc welding methods now available in the United States. The new process is based on the use of a coated wire which is known as " West-ing-arc MS-20 " wire. While the consumable electrode process has been used for several years to weld stainless steels, aluminium and other non-ferrous metals, this latest development is now said to bring all the advantages of the process—speed, higher

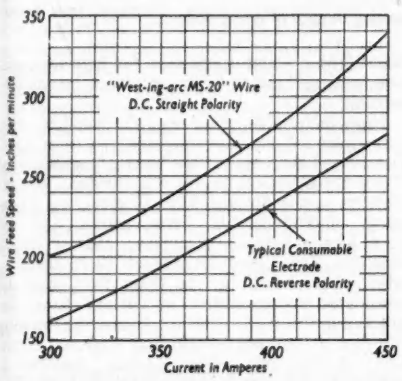


Fig. 1—Curve of deposition rates showing the higher wire feed speed of " West-ing-arc MS-20 " wire over a typical consumable electrode.

quality, cleaner welds—to the welding of mild steel at economical operating costs. The new process produces welds that can be painted without cleaning. There is virtually no spraying or spatter, nor is there any slag-covering on the weld. The new process may be used on mild steels, with or without normal mill scale, on thicknesses from $\frac{1}{16}$in up. It can be used as either a semi-automatic process with an operator holding the gun, or as an automatic process with the gun being clamped into position and the work moved or where the wire is fed through an automatic head. The wire, or consumable electrode, is made of mild steel of special analysis in four sizes varying from 0·040in to 0·091in in diameter. Certain materials are coated on the wire by means of a special manufacturing process. Although electrode coatings in general are by no means unusual, the one on the " MS-20 " wire is said to facilitate the high performance standards of the new welding process.

It is well known that the amount of metal an electrode deposits, and consequently the welding speed, is determined by the rate at which the electrode burns for a given welding current. The burn-off rate is, in turn, affected by the polarity of the welding process. Using a bare wire, with straight polarity, the burn-off rate is 1·8 times that with reverse polarity. However, it has been found that straight polarity with a bare wire results in poor arc stability, heavy spatter, extremely low penetration, and, generally, unsatisfactory welds. Consequently, the higher burn-off rates of straight polarity operation are usable only if these major objections can be overcome. The new process, in contrast to most other processes of this kind, uses straight polarity. The special coating on the " MS-20 " wire makes it possible to take advantage of some of the higher burn-off rates because it stabilises the arc, eliminates spatter, and provides good penetration. Comparison curves of deposition rates of " MS-20 " $\frac{1}{16}$in diameter wire and that of a typical $\frac{1}{16}$in diameter consumable electrode are shown in the above illustration. These curves show that the " MS-20 " wire facilitates from 15 to 22 per cent faster wire feed speeds depending on the welding current used. Since the arc is extremely stable and is free from wasteful spatter, the wire feed speed is a direct measure of the actual welding speed for a given size of weld. Tests have established that the physical properties of the welds are superior to those obtained using either automatic or manual coated-electrode processes. The excellent physical properties which have been found at low temperatures mean a weld low in contaminating oxygen and nitrogen.

The electrode gun is rated at 500A, is light in weight and is well balanced. The control for feeding the wire has been designed to supply wire at a constant preselected speed under all loads. Both of the drive rolls are driven through a $\frac{1}{12}$ h.p. d.c. geared motor. The electrode length beyond the tip of the gun is controlled on stopping so that neither the wire nor the operator's time is wasted by trimming. The control panel is light in weight and operates from a conventional 110V, a.c. supply. An adjustable water pressure switch prevents operation of the unit when the water pressure is below a predetermined limit. The constant potential selenium rectifier d.c. power supply unit has a continuous current rating of 500A at a 34V load. One of its main advantages is the relatively flat volt-ampere characteristic which it produces. The volt-drop from no load to full load is only 6V. This characteristic helps greatly in producing a maximum arc stability and in ensuring quick starting and recovery. The power unit may be used with either consumable electrode, inert gas metal arc, or submerged arc welding processes. No current adjustments are necessary at the welding set since it is automatically regulated by the rate at which the wire is fed into the arc. The set has an efficiency of about 82 per cent, and the power factor is in excess of 95 per cent at continuous rated load.

An interesting spot welding application of the shielded inert-gas fusion welding process was demonstrated by the Air Reduction Sales Company, of New York. The so-called "Aircospot " gun is a light, water-cooled manual welding unit that produces joints which are said to be comparable to spot welds made with costly automatic resistance welding machines. It can be used with any d.c. motor generator or rectifier welding set that provides a current up to 250A with an open circuit voltage of at least 55V. The gun utilises an inert-gas shielded tungsten arc to join two pieces of light-gauge steel or to weld light-gauge steel to heavier sections. It eliminates the use of back-up plates and complicated jigs and fixtures and the weld itself is completely protected from atmospheric contamination by the inert-gas shield. Squeezing the trigger of the gun begins the welding cycle, which is fully automatic. The circuits in the control panel start the flow of gas and water before the arc is struck, and keep them flowing for a short time after the weld is completed. The trigger squeeze brings the non-consumable thoriated tungsten electrode into contact with the work. The electrode then retracts automatically to establish an arc of preset length. A timer, which is adjustable from 0 to 6 seconds, extinguishes the arc at the end of the chosen time interval. An interlock is provided to prevent damage if the cooling water supply should fail.

At the stand of the Lincoln Electric Company, of Cleveland, Ohio, there was a display of the " Twinarc " tandem automatic submerged-arc welding equipment combined with the " Spreadarc " oscillating attachment. With the " Twinarc " equipment, two continuous electrodes are fed simultaneously in place of the single continuous electrode with conventional automatic arc welding in granular flux. The result is a selective spreading of the arc to suit the conditions of the job, enabling the use of higher currents with increased melt-off rates and higher speeds. The welding currents are supplied by the same generator used with the single arc. The currents are governed by the same machine controls, thus eliminating the need for additional control mechanism. The welding currents are equally divided between the two continuous electrodes, permitting the use of welding currents up to 1500A. The tandem unit provides a wide range and versatility of operation for almost every kind of joint. For normal seam welding on butt and fillet joints having a good fit-up, the twin electrodes are lined up in tandem with the joint, permitting high welding speeds and best penetration. Where a wide bead is desired at slow speeds, as on heavy fillets or with a poor fit-up, the tandem head may be simply rotated up to 90 deg. across the seam. The spacing between the two electrodes can be varied by changing a central contact block. The tandem welding head assembly is bolted to the " Automatic Lincolnweld " unit in place of the conventional single electrode jaw assembly. A simple change of drive rolls and guides in the drive roll mechanism and the installation of a new wire reel bracket is all that is required in addition. The following table indicates the speeds obtainable with this equipment in butt welding, using two $\frac{3}{32}$in diameter electrodes (see

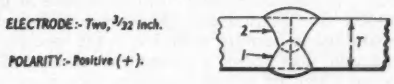


Fig. 2—Butt welding with automatic " Twinarc " equipment.

diagram), positive polarity and an electrode position in tandem along the seam.

Welding Speeds Obtainable with "Twinarc" Welding Equipment

Plate thickness " T "	Pass No.	Current, amperes	Voltage, volts	Speed, in per min
$\frac{3}{8}$in	1	750	34	42
	2	1000	36	42
$\frac{1}{2}$in	1	1000	36	40
	2	1200	38	40
$\frac{5}{8}$in	1	1050	36	34
	2	1300	38	34
$\frac{3}{4}$in	1	1200	36	30
	2	1400	39	30

The " Spreadarc " oscillating attachment may be mounted on any " Lincolnweld " automatic welding head to make wide pads of weld deposit. It may be used to deposit a hard surfacing layer for wear resistance or to build up with mild steel. Under proper conditions it may also be used to help bridge the gap where poor fit-up is encountered in welding. The attachment oscillates the holding head at right angles to the direction of travel. The combined oscillation and forward motion produce a uniform pad up to 4in wide in a single pass. There are only two controls : the width of oscillation, infinitely variable from 0 to maximum, is set by a single eccentric adjustment, and the number of oscillations per minute is set by a rheostat control giving a continuous range of speeds.

At this year's exposition there was practically no new equipment shown in the field of resistance welding, an exception being the " Weldpower PW–1 " percussive welder built by the Raytheon Manufacturing Company, of Waltham, Massachusetts. This unit has been designed primarily for welding metal studs or special pieces to ferrous or non-ferrous parts. It provides a fast, reliable production method of attaching studs directly to a wide variety of metals and alloys. Thus, it eliminates the time, expense and equipment required for less satisfactory or more complicated methods such as drilling and tapping, soldering and brazing. Moreover it does not require special treatment or manufacture of the studs or pieces in order to effect a satisfactory junction, and the studs may be simply cut off from wire stock. Operating on the stored energy principle, the unit supplies precise values of welding current in an accurately timed welding sequence which applies a pre-adjusted forging force percussively at the instant when the abutting surfaces are heated to fusion temperature. The results are clean, strong, uniform welds with little or no marking of the stock. Studs ranging from 0·050in to $\frac{3}{16}$in in diameter can be welded by the machine. The percussive welder receives its welding energy from a bank of storage capacitors which are charged by a full-wave rectifier. The welding heat selected is regulated and is held constant regardless of

any power line fluctuations. Depressing the foot pedal actuates the air-operated head. At the instant of weld initiation, the capacitor bank is connected to the electrically isolated work pieces and an arc is established between them to heat the abutting surfaces. The work pieces are then brought together sharply by the head. The head velocity, forging force and capacitor discharge current are all precisely controlled in magnitude and time relation to provide welds of constant strength and uniform appearance. The heat effect is confined to the weld area and there is little or no loss of strength through annealing. The weld penetration is shallow, usually leading to no marking of the opposite face of the work.

The Gamma Corporation, of Mansfield, Massachusetts, displayed two interesting devices for handling the iridium-192 isotope for purposes of industrial radiography. The firm's iridium "Gammatron" is used to handle an iridium-192 source by remote control from a distance of up to 50ft for internal and panoramic exposures or to direct a beam of radiation at the specimen. The unit also serves to store the iridium-192 source when not in use—shielding the source so thoroughly that unexposed film can be stored within a few feet of the machine. The device consists of a shield within which the source is stored when not in use, a mount, which allows the head to be aimed in any direction when the machine is used as a beam producer, and two sets of control cables and source tubes. The unit has a capacity of over 75 curies of iridium-192, and is shielded to allow less than 6 milliröntgens per hour at 24in when fully loaded.

The company's iridium "Isotron" is a device for the remote handling of very strong sources of iridium-192 in industrial radiography. Such sources may be exposed at distances up to 50ft from the operator, who can expose the source while remaining behind the protection afforded by a concrete wall or a shield. The unit was specifically designed for panoramic exposures, where several specimens are arranged around the source and "shot" simultaneously, and for internal exposures where the source is exposed within a cavity in the specimen and the film is wrapped around the outside. The machine consists of three principal components: a shield, within which the source is stored when not in use, a flexible tube 25ft long, through which the source travels to the predetermined point of exposure, and a 25ft control cable, at the end of which is a control box used to move the source from the shield to the end of the flexible tube. The flexible tube may be replaced with a rigid tube of any length up to 25ft. While these tubes are rigid, they may be bent around moderate radii for insertion through ports in vessels or into hollow castings, or for fixed panoramic set-ups, and they will retain their positions while the source passes through them. They are most useful where a series of shots of the same approximate geometry are to be made. The device is mounted on a magnesium handcart, which allows it to be moved easily to the point of use. Its total weight is only 125 lb.

A new portable industrial X-ray installation was demonstrated by the X-ray department of the General Electric Company, Milwaukee, Wisconsin. The so-called "OX-175" apparatus consists of a tube head, a control unit and interconnecting cables. With a tube head weight of less than 185 lb, a diameter of 10½in and a length of only 42in, the machine can be used in relatively inaccessible places. The control, measuring only 18in by 18in by 14in, weighs less than 145 lb and is contained in an easily transported metal case which will withstand adverse weather and field usage. The connecting cable is in various lengths up to 200ft, so that the head, in many cases, will be the only component transported to the scene of radiography. To give it the widest possible application the unit is available with two different fields of radiation, and two different duty cycles. When equipped with a flat target tube it can be operated at 5mA, 45kV to 175kV peak, and will produce a 360 deg. field of radiation about the long axis of the tube head. When fitted with an angle target tube the unit will operate at 8mA, 175kV peak, and will cover a 14in by 17in film at a 24in distance. One

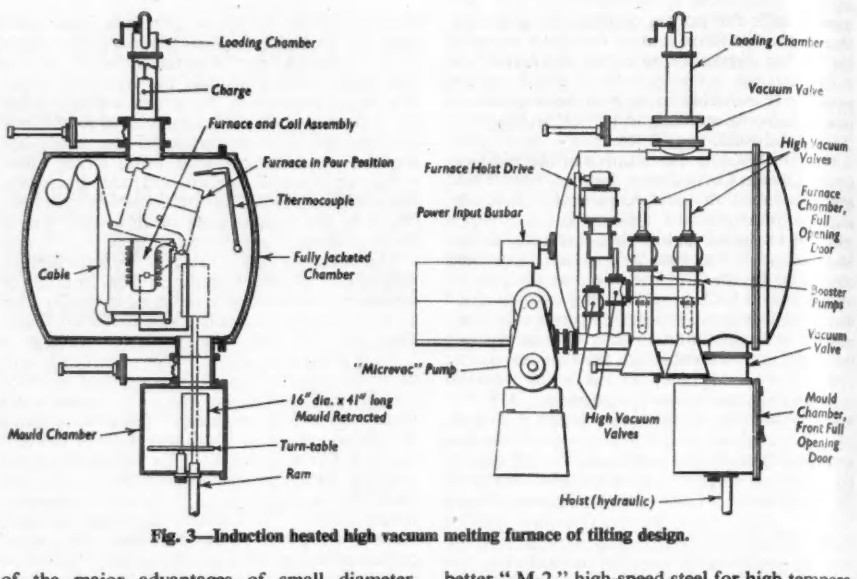


Fig. 3—Induction heated high vacuum melting furnace of tilting design.

of the major advantages of small diameter, lightweight X-ray equipment is that it allows the operator to place the unit inside vessels. The "OX-175" set, when equipped with a tube to produce a 360 deg. field of radiation, can be placed inside a circular vessel, and in one exposure can radiograph an entire circumferential weld. Even when operating with the angle target tube, placing the unit inside the object to be radiographed results in substantially more radiographic coverage with a more uniform intensity field than if the same unit were used to radiograph the object from the outside.

Several displays at the Metal Show this year illustrated the growing importance of vacuum-cast metals. Representative in this respect was the stand of the Carboloy Department of the General Electric Company, Detroit, Michigan, which exhibited various applications of vacuum-cast metals and alloys. This activity originated in 1946 at the General Electric Research Laboratory in Schenectady, and now has advanced to the point of the Carboloy Department's announcement of its commercial vacuum melting business. During this eight-year period considerable experience has been gained in the development and use of equipment, and the obtaining of data and characteristics on vacuum-melted metals and alloys. The Carboloy organisation has also been working closely with the General Electric Research Laboratory and the company's Aircraft Gas Turbine Division so that to date, more than 100,000 lb of various alloys have been vacuum melted in the General Electric facilities. At present the Carboloy Department is carrying on its vacuum melting activities at Schenectady, New York. Early in 1955 a new pilot plant vacuum melting facility will be installed in Detroit. Furnaces ranging in capacity from 10 lb to 1000 lb will then be in operation.

Basically, two major areas of development are opened by the techniques of vacuum melting. The first one is the development of new alloys, tailored to answer specific problems by the incorporation of hitherto unavailable physical and chemical properties. Examples include "1570," a new alloy designed specifically for jet engine buckets, with less nickel but more cobalt and a higher titanium content. Furthermore, "M-252" is a nickel-base alloy strengthened with moderate amounts of titanium and aluminium. As an air-melted alloy it has been used for jet engine turbine buckets for several years. Now, by vacuum melting, its properties are considerably improved and the uniformity of these properties will greatly increase its use for jet turbines. The second major advantage is the improvement of properties of existing metals and alloys. In general, these improvements are in the fields of cleanliness, control of chemical composition and physical and mechanical properties, hardenability, and workability. Laboratory data and experience has already shown that common alloys, such as the S.A.E. 52100 steel, have greatly improved fatigue strength when vacuum melted. Furthermore, gas-free copper and a better "M-2" high-speed steel for high temperature bearings have also been produced by vacuum melting.

High-vacuum furnaces were exhibited by four companies: the Consolidated Vacuum Corporation of Rochester, New York; the National Research Corporation, of Cambridge, Massachusetts; the Optical Film Engineering Company, of Philadelphia, Pennsylvania, and the F. J. Stokes Machine Company, also of Philadelphia. The tilting furnace of 50 lb capacity which was shown by the latter firm, may be considered representative of current American practice in this field. The accompanying drawing shows a diagrammatic side and sectional elevation of this unit. The loading chamber is mounted above the main horizontal vacuum chamber. Below it is the mould chamber, containing the mould in which the ingot is cast when melting and refining are completed. An advantage of the external mould with a vacuum valve between it and the chamber is that this can readily be adapted to hold a train of moulds for making several castings from the same melt. A supplementary loading chamber through which additions can be made to the material in process can be provided if required. The furnace is fitted centrally in the vacuum chamber and can be tilted into the pouring position by a cable. Simple as the furnace is in principle, it incorporates a design which affords remarkable flexibility. Both crucible and coil assembly can be arranged to take care of additional capacity. There are six buckets in the "additions-maker" of the unit with generous capacity for the needed additions to the material in process. The buckets can be emptied partially or fully in any sequence and at any time; then, if necessary, they can be withdrawn, recharged and returned for further loading. Vacuum locks are provided to give perfect and safe control while additions are made to the melt. They also enable the furnace to maintain specified degrees of vacuum and outgassing.

The vacuum pumping system of the furnace is sized to allow the furnace to operate at any specified pressure. The pumping system is remotely controlled and has pneumatically-operated poppet vacuum valves. The booster pumps are of a special design which enables them to operate in the diffusion pump range when required. They operate normally at 1 to 1000 microns but will blank off at 0·001 micron. The furnace chamber is a horizontal cylindrical tank. A fully-opening "O"-ring gasketed door allows easy access. The chamber is fully water-jacketed, and the mould lock is situated on the centre-line of the bottom of the chamber. The induction heating system of the furnace comprises an induction coil, contacts to permit tilting of the coil, and power leads on the furnace shell. The motor generator set, the controls and the capacitor bank are mounted externally. The furnace is at present available in capacities of 10 lb, 30 lb, 50 lb, 100 lb, 400 lb, 1000 lb, and 2000 lb of steel.

Industrial and Labour Notes

Overseas Trade Report

Figures about the United Kingdom's overseas trade in November, which have been issued by the Board of Trade, give the value of exports as £195,600,000. Imports recorded during November reached the high figure of £333,800,000. It will be recalled, however, that, when the October figures were announced, it was explained that on account of the recent dock strike it would probably be two or three months before the trade returns reflected settled conditions.

The Board of Trade says that recorded imports have reacted more quickly than recorded exports to the end of the strike, one obvious reason for that being that ships had to be unloaded before they could take on waiting exports. Another reason is that there are some differences of timing between the recording of imports and exports. Even if the figures for October and November are considered together, the effects of the strike are still evident. For the two months, the recorded value of United Kingdom exports averaged £205,700,000 a month, which was 7 per cent below the average in the preceding quarter, and 12 per cent below the October-November, 1953, average. Imports in October and November this year averaged £281,000,000 a month, which was about the same as the average from January to September and 2 per cent above the October-November, 1953, rate. Re-exports in October and November averaged £7,300,000 a month, which was 15 per cent below the monthly average over the first three quarters of this year.

Industrial Production

The information division of the Treasury has stated that industrial production in the United Kingdom in the first ten months of this year was between 5 and 6 per cent higher than in the comparable period of last year. On a seasonally corrected basis, there was a rise of nearly 2 per cent between the first and second quarters of this year and a rise of about 1 per cent between the second and third quarters. The Treasury says that the United Kingdom's advance in industrial production in the first half of this year was about in line with that of Western Europe as a whole ; it was much the same as that of France, Belgium and the Netherlands, but was not up to the 11 per cent increase achieved by Western Germany.

The Treasury's statement goes on to show that, in the first half of this year, manufacturing output in the United Kingdom was rather more than 8 per cent higher than a year earlier (compared with 7 per cent for all industries). The three manufacturing industries which exceeded the average were paper and printing with a 21 per cent increase ; vehicles with a 13 per cent increase, and chemicals, where the increase was 12 per cent. Another substantial contribution to the total increase in manufacturing production has come from the engineering, shipbuilding and electrical plant group of industries in which expansion this year has been at about the average rate for all industries. Within this group, completions of merchant ships have been a post-war record, the completion rate in the first nine months being 25 per cent greater than in the corresponding period of last year. Electrical engineering output in the first half of this year was 7½ per cent up on a year earlier, though the quarterly rate was lower than in the last quarter of 1953 ; mechanical engineering output in the first half of this year was 4 per cent higher than a year earlier and was, in fact, better than in any period of 1953.

Commenting on the factors which have led to the rise in production this year, the Treasury mentions exports, where the volume increase has been of the order of 9 per cent, and personal consumption at home, which has been 3 per cent higher this year. Durable consumer goods, it is stated, have been selling more readily, and sales of cars in this country have been a major factor in rising output. More building work has stimulated output in the building materials and other industries, but the Treasury suggests that the growth of factory building work and the increased flow of orders for plant have yet to show their influence in a marked rise in output from the engineering trades. It is here, the Treasury comments, that further improvement would be welcome, not least for its effect in fortifying the competitive power of the economy. Much of this year's extra output, it is added, has been derived from higher productivity, and average employment on production in the first half of the year was 2 per cent greater than a year earlier. Thus, the output increase of 7 per cent suggests that output per man rose by something like 5 per cent. Future increases in employment are likely to be smaller, and, the Treasury says in its statement, "it is from higher productivity, for which we must look mainly to increased industrial investment, that further expansion must be sought."

Railway Wages

Last Monday evening, the Minister of Transport, Mr. Boyd-Carpenter, received representatives of the National Union of Railwaymen and discussed with them the railway wages situation. Prior to the meeting, the N.U.R. had suggested that the Government should consider restoring to the railways part of the £124,000,000 profit made from railway operation between 1940 and 1946. This suggestion was put forward in view of the British Transport Commission's contention that its present financial state did not permit any further railway wage increase.

After last Monday's meeting an agreed statement was issued which said that the Minister told the N.U.R. representatives that he could not contemplate anything in the nature of a subsidy to help the British Transport Commission to meet new railway wage claims. The Minister said that he was deeply concerned about the future of British Railways, and believed that three things were required to put the railways on a sound basis ; these were modernisation of railway equipment, greater freedom of charges, and redeployment of labour. The Minister recognised, the statement continued, that these were long-term measures, the full benefits of which might not be felt for several years. He added that the £124,000,000 which accrued to the Government as the result of wartime operation of the railways was little more than a book-keeping transaction. The Minister said that he would like to consider the points put forward by the deputation and to have an opportunity to consult his colleagues in the Government without delay on these matters. Meantime, the statement ended, the door to negotiation and arbitration was still open and the Minister urged that the union should reopen talks with the British Transport Commission.

Coal Production

This week the National Coal Board has published a statistical statement about the costs of production and proceeds of colliery operation in the third quarter of this year. The total amount of coal "disposable commercially" during the quarter was 44,546,757 tons, mine consumption was 2,129,609 tons and miners' coal allowances took up 1,104,189 tons. Total production costs amounted to £151,531,624 and the proceeds of sales of coal to £151,579,210, so that there was a profit, before charging interest, of £47,586. The Board estimates that profit during the quarter on opencast working came to £750,000 and that the profits of its ancillary undertakings were £240,000. The overall proceeds for the quarter were thus £1,037,586. The Board's financial loss on imported coal, however, was £2,050,000 and a further deduction of £155,000 is made under the heading "interest payable, less interest receivable and other income." At the same time, there was a reduction, amounting to £1,800,000, in the provision made by the Board for taxation.

Taking all these items into account, the Board's estimated net profit for the third quarter was £632,586. The interest payable to the Minister of Fuel and Power has been put at £4,650,000, with the result that at the end of the quarter the accounts showed an estimated deficit of £4,017,414. About production costs, the statement says that wages, including holiday pay and allowances in kind, took up £92,662,476 ; roof supports, general stores and repairs came to £25,760,164 ; coal and power consumed cost £8,214,649, and other costs, including depreciation, amounted to £24,894,335. During the third quarter the average weekly cash earnings of all underground workers were £11 4s. 9d., and of surface workers £8 15s.

The latest report on the coal situation from the Ministry of Fuel and Power says that last week's deep-mined production amounted to 4,535,100 tons and opencast production to 151,800 tons, giving a total saleable output for the week of 4,686,900 tons, compared with 4,847,600 tons in the corresponding week of last year. In the first forty-nine weeks of this year, ended last Saturday, the total saleable output of coal was 212,435,800 tons. At the end of last week the chairman of the National Coal Board, Sir Hubert Houldsworth, was present at a meeting of the executive of the National Union of Mineworkers. It was stated subsequently that Sir Hubert told the union leaders that there was now no chance of winning the additional 3,000,000 tons of coal which had been hoped for this year. Production from the deep mines had so far this year been greater by some 1,900,000 tons, but output from opencast workings had declined and was less than 90 per cent of that achieved last year.

National Production Advisory Council on Industry

A meeting of the National Production Advisory Council on Industry was held in London on Friday last under the chairmanship of Mr. H. Brooke, Financial Secretary to the Treasury. A statement circulated after the meeting said that the general picture presented in reports from the regions showed a continuing high level of industrial activity and employment. Slight seasonal increases in unemployment had been reported from some regions, but the large industrial centres such as London and the Midlands had again referred to shortages of skilled labour. The statement went on to say that some concern had been expressed by the Eastern Regional Board over the planning and labour problems which would arise from further projects for major industrial developments in the Luton-Dunstable area, particularly in the motor vehicle industry.

A report on factory building, submitted by the Minister of Works, showed that since 1951 the total sums spent on work done had risen year by year from £161,500,000 in 1952 to an estimated £186,100,000 this year. In the same period the rate of approvals for new building, as reflected in industrial development certificates issued by the Board of Trade, had risen still more sharply and this year had run ahead of the amount of work in progress. The report indicated that in every region the value of the work done in 1954 was likely to exceed that done in 1952. The increase in total output was likely to be about 19 per cent, the increases varying from about 2 per cent and 3 per cent in the London and South East and Eastern regions to 50 per cent in the Northern region.

A memorandum prepared by the Iron and Steel Board examined the possible demand and supply position for steel sheet during the next few years. It showed that steel sheet taken by home users and exports had risen from 1,775,000 tons in 1952 to 1,804,000 tons in 1953, and in the first nine months of this year the total had reached 1,615,000 tons. The memorandum said that development schemes in hand should begin to mature in 1956, but meanwhile there was little expectation of any substantial increase in output.

Notes and Memoranda

Air and Water

LAUNCH OF H.M.S. "RUSSELL."—On December 10th the anti-submarine frigate H.M.S. "Russell" was launched from the shipyard of Swan, Hunter and Wigham Richardson, Ltd. The ship has an extreme length of 310ft, a length between perpendiculars of 300ft, and a beam of 33ft, and is propelled by geared turbine machinery of advanced design, built by the Wallsend Slipway and Engineering Company, Ltd. Three Bofors guns and two three-barrelled anti-submarine mortars will form the armament.

OIL TANKER FILM.—On Wednesday of last week a film produced by the Shell Film Unit, entitled "Proud Ships," was given its first showing. The film, although it is the story of the voyage of one tanker, serves to illustrate the operations and the work of the tanker fleets, life at sea and also the activities at a refinery and oil storage installations. Apart from the marine sequences, some idea is given of the world-wide operations, the scope and magnitude of the oil industry and the system controlling the movement of ships and cargoes. The film which has a running time of twenty-four minutes, is available in 16mm and 35mm sizes and can be borrowed free of charge from the Petroleum Films Bureau, 29, New Bond Street, London, W.1.

GOLDEN JUBILEE.—To mark the occasion of its golden jubilee The Rowhedge Ironworks Company, Ltd., Rowhedge, near Colchester, has issued a booklet descriptive of the years from 1904 to 1954. The founding of the company in 1904 is detailed and there are some notes about early shipbuilding on the site. There are short descriptions of a selection of craft, accompanied by photographs which show the wide variety of small vessels, such as yachts, tenders, tugs, ferries, and passenger and river steamers, built at the yard, many of which are in service all over the world. The work of the engineering department of the company is illustrated and mention made of constructional steelwork and other activities of the company.

INSTITUTION OF NAVAL ARCHITECTS.—We are informed by the Institution of Naval Architects that it has been found necessary to amend the dates of the spring meeting, 1955, and the following is the revised programme. On Tuesday, April 5th, papers will be read at morning, afternoon and evening sessions, the latter being a joint meeting with the Institute of Marine Engineers. The annual general meeting and the reading of a paper will take place during the forenoon of Wednesay, April 6th, and in the afternoon another paper will be presented, while the annual dinner will be held at the Conriaught Rooms in the evening. An invitation to hold the 1955 autumn meeting in Yugoslavia has been received, and the following is the suggested provisional programme :— The reading of papers in Rijeka and visits to shipyards from Monday, September 19th to 22nd, followed by a Dalmatian coast cruise to Dubrovnik and Kotor, and back to Rijeka, and a visit to the shipyard at Split during the period from Friday, September 23rd to 27th.

Miscellanea

CORRECTION.—In our issue of December 3rd, page 788, we published a description of the "Vacu-Blast Junior," portable blast cleaning machine, in which we stated erroneously that the action of this machine was intermittent, whereas in fact this unit is completely regenerative. The paragraph concerned applies to the "Model NC" machine which is non-cycling. We are asked to make it clear, however, that in the "NC" model the grit is transferred automatically from the top to the bottom section, once the air pressure has been turned off.

TEST BED DYNAMOMETER FOR CENTRIFUGAL PUMPS.—A 3300V, three-phase, submersible motor of 1000 h.p. capacity has recently begun trials at the Luton, Beds, factory of Hayward Tyler, Ltd. The water cooled housing is mounted horizontally between ball bearings, with a balance showing on a dial the load on the torque arm. This, together with the reading from the shaft-mounted electric speed indicator, allows the output to the pump under test to be calculated. The unit will later be set up vertically and will form part of the firm's test bed equipment.

HEAVY DUTY PLUGS AND SOCKETS.—Plugs and sockets for temporary electric cables which will withstand rough conditions are being manufactured by The Plessey Company, Ltd., Ilford, Essex. The four kinds made are a cable terminal and anchor, a panel unit with flange for mounting in a fixed position, a similar unit but with a cable connection at the rear, and a cable coupler to be used in conjunction with the terminal in order to join two cables. The forged aluminium-bronze housings will withstand the load of vehicles passing over them and are dirt and weather-proof. Three standard contact combinations are made, suitable for up to 440V a.c. and 50A.

PINKSTON POWER STATION EXTENSIONS.—Extensions costing over £2,000,000 were opened on December 3rd by Mr. Thomas Johnston, chairman of the North of Scotland Hydro-Electric Board, at the Pinkston power station of the Glasgow Corporation Transport Department. The principal unit in these extensions is a 30MW, 3000 r.p.m., turbo-generator set, which with other equipment has been supplied by Metropolitan-Vickers Electrical Company, Ltd. The new generating set has a two-cylinder turbine designed for steam conditions of 600 lb per square inch gauge, 850 deg. Fah. at the turbine stop valve. The high pressure cylinder contains twenty-three stages of stainless steel impulse blading, whilst the double-flow, low-pressure cylinder has six stages of stainless steel blading in each flow. Five stages of feed water heating are incorporated, the final feed water temperature being 345 deg. Fah., and the turbine exhausts at a vacuum of 28·7in Hg. to a condenser supplied by G. and J. Weir, Ltd., having a cooling surface of 28,000 square feet, taking 28,000 gallons of cooling water per minute at 70 deg. Fah. The air ejector has also been supplied by G. and J. Weir, Ltd. The generator, which is rated at 35,295kVA (0·85 p.f.) and generates at 6·6kV, is generally of Metropolitan-Vickers standard design. Ventilation is provided by two external cooling fans and a system of radial ducts with multiple inlets. The generator is designed for a short-circuit ratio of 0·75. It is provided with direct-coupled main and pilot exciters.

BRITISH ASSOCIATION OF MACHINE TOOL MERCHANTS.—At the fourteenth annual general meeting of the British Association of Machine Tool Merchants (Incorporated), Mr. A. V. Graves (E. H. Jones (Machine Tools), Ltd., of London, N.W.9) was unanimously elected president of the association to serve during the ensuing year in succession to Mr. A. W. V. Agutter (Centaur Tool Works, Birmingham), who remains on the council as the immediate past president. Mr. E. Heliot (The Heliot Machine Tool Company, London, S.E.10) was elected vice-president and Mr. E. J. F. Bradley (Pidgen Bros., Ltd., London, E.C.1) was re-elected honorary treasurer.

ALUMINIUM IN BUILDING.—The Northern Aluminium Company, Ltd., has published a brochure with the title "The Durability of Aluminium in Building," which explains how exposure to weather affects aluminium and gives evidence of the behaviour of the metal under various conditions. A short list indicates the alloys used in building and a note on their behaviour in corrosive environments is followed by experimental evidence of the durability of aluminium and its alloys, together with an outline of experimental work carried out in America and characteristic corrosion/time graphs. A number of case histories are examined and the question of contact with other building materials and also protective and decorative finishes briefly discussed.

A GLUE PEN.—A form of adhesive dispenser, known as the "Fastik" glue pen, has been developed by the Glue Pen Co., 71, North Circular Road, London, N.W.2, to provide a simple, clean means of applying a quick-setting glue to papers, labels, &c. The pen consists of a tubular metal holder which houses a replaceable container of quick-setting glue. The container is screwed into the holder head which has an orifice at the top sealed by a spring-loaded taper plug. When this plug point is placed on a piece of paper and pressure is applied it is pushed back, and a small drop of glue is ejected. By depositing a series of drops of glue on the surfaces to be stuck they can be made to adhere quickly by pressing them firmly together.

HIGH SLOPE MINIATURE PENTODE.—A miniature pentode with a mutual conductance of 16·5mA per volt is being produced by Mullard, Ltd., Century House, Shaftesbury Avenue, London, W.C.2. It is the "E180F," and is intended for wide-band amplifiers such as radar i.f., television, and carrier telephone equipment. Its performance is attributed to the technique of assembling the control grid which allows it to be spaced only 0·0024in from the cathode. Instead of wedging the grid wires into notches in the support rods, the wires here are wound on accurately ground rods which are spaced by spring supports at each end. Anchored by glass cement, and gold-plated to reduce emission, the grid wires maintain their clearance accurately even when the valve heats up.

STUDENT MANUAL.—The fourth edition of its student manual has been issued by the W. T. Henley's Telegraph Works Company, Ltd. This book is intended primarily for the benefit of young men entering the company's service. It gives a brief history of the company and then describes the Henley education scheme and the general educational facilities available for young people in the company's employment. It lists educational establishments available ; the courses and examinations which are open to students, and the conditions and purposes of student apprenticeships and trade apprenticeships. The brochure is well illustrated with reproduced photographs showing views in the company's various factories and examples of its products and constructional work.

OBITUARY.—We have learned with regret of the death of Mr. Edward Townsend Hippisley, M.I.E.E., which occurred at 60, Lillington Road, Leamington Spa, on December 9th. Since 1936, he had been the manager of the traction department (sales and engineering) of the British Thomson-Houston Company, Ltd. Mr. Hippisley joined the company in 1920, when he started a three-year post-graduate apprenticeship. He entered the traction department in 1923 and from 1929 was responsible for heavy traction contracts involving electric and diesel-electric locomotives. . . We also record with regret the death of Mr. William F. Drake, which occurred suddenly at his home at Tiverton, Devon, on December 10th. Mr. Drake had completed forty-eight years in the service of Stenners of Tiverton, Ltd., and for some years past had had charge of the company's sales office.

MERCHANTING TRANSACTIONS IN STRATEGIC GOODS.—The Strategic Goods (Control) Order, 1954, which comes into operation on January 7, 1955, prohibits the disposal of specified strategic goods which are situated outside the United Kingdom to any authority of or person in the Soviet Bloc or China, or to any other person if the person disposing of the goods has reasonable cause to believe that they will be imported into the Soviet Bloc or China. The goods affected by this Order are those which are subject to embargo for Soviet Bloc countries. This Order was foreshadowed by the President of the Board of Trade on July 26th last, when he announced in Parliament that the countries which co-operate in maintaining restrictions on exports to the Soviet Bloc had reached agreement on a substantial reduction in the lists of goods under control. The President said that side-by-side with this, the enforcement of control over items on the reduced list would be improved. Countries not already controlling the transit of goods would take steps to introduce controls in line with the transhipment control which the United Kingdom had operated since 1951. The United Kingdom, for its part, would supplement this action by imposing control over merchanting transactions in strategic goods for the Soviet Bloc.

LOEWY ENGINEERING COMPANY, LTD.—The company has now moved into its newly-built offices at Wallisdown Road, Bournemouth. At a house-warming party held there last week, Mr. K. Guttenstein paid tribute to the late Mr. Ludwig Loewy, who founded the firm in 1936. Proposing the toast, "Designers and Innovators as an Aid to Productivity," Sir Edward G. C. Boyle, Bt., M.P., Parliamentary Secretary to the Ministry of Supply, recalled the part played by the company's equipment in the armament programme of 1938 and subsequent years, and stressed the facts that within the last four years the company's turnover had twice exceeded £2,000,000, and that an average 66 per cent had been exported, much of it to dollar countries. By designing equipment for the British steel and metal industries much foreign currency had been saved. The budgets of the last two years set out to stimulate capital investment, e.g. by this year's special investment allowance which should greatly assist makers of production equipment. Both expansion of exports and savings on inessential imports were necessary, Sir Edward said, if we were to earn our living in the markets of the world.

Personal and Business

MR. H. W. M. KING has been elected vice-chairman of Geo. W. King, Ltd., Stevenage, Herts.

MANCUNA ENGINEERING, Ltd., states that it is building a single-storey factory at Denton, Manchester.

SIR STEPHEN TALLENTS, K.C.M.G., has been elected president of the Design and Industries Association.

SHEEPBRIDGE EQUIPMENT, Ltd., Chesterfield, announces that it is to build Jules Weitz tower cranes, under licence.

HOPKINSON ELECTRIC COMPANY, Ltd., Cardiff, states that Mr. Percy Evans, general sales manager, has been appointed sales director.

WORDREW, Ltd., 173, Princess Street, Manchester, has acquired extended warehouse premises at 185, Princess Street, Manchester.

THE MINISTRY OF SUPPLY announces the appointment of Mr. S. F. Follett as principal director of equipmen t research and development (air).

BRUCE PEEBLES AND CO., Ltd., Edinburgh, states that its works will be closed for the New Year holiday from Friday, December 31st, until Thursday, January 6th.

ALUMINIUM (CANADA), Ltd., is the new title of the company formerly known as Stand, Ltd. Its address is 11, Bruton Street, London, W.1 (telephone, Mayfair 9721).

W. B. DICK AND CO., Ltd., states that Mr. J. S. Rolph, general manager of the marine department, and Mr. R. F. Baldwin, general manager of the electrical department, have been appointed directors.

DR. MAURICE COOK, joint managing director of the Metals Division of Imperial Chemical Industries, Ltd., has been elected chairman of the British Non-Ferrous Metals Research Association.

THE BRITISH BROADCASTING CORPORATION announces the appointment of Mr. C. R. Jephcott, A.M.I.E.E., as engineer-in-charge of the temporary television transmitting station at North Hessary Tor, South Devon.

JOSEPH GILLOTT AND SONS, Ltd., LEHMANN, ARCHER AND LANE, LTD., and SIGMA INSTRUMENT COMPANY, Ltd., have recently become member companies of British Engineers' Small Tools and Equipment Company, Ltd., Buckingham House, Buckingham Street, London, W.C.2.

THE ORIENT STEAM NAVIGATION COMPANY, Ltd., announces that Mr. J. D. Cameron, who has completed forty-five years' service with the Orient Line and has been superintending engineer since 1938, retired on November 30th, and has been succeeded by his assistant Mr. H. Knight.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., states that Mr. P. R. Dunn, M.I.E.E., has been appointed chief engineer in succession to Mr. D. T. Hollingsworth, who has been elected a director. The company states also that the address of its Middlesbrough district office has been changed to 55–57, Borough Road, Middlesbrough (telephone, Middlesbrough 43644).

Contracts

THE BRIGHTSIDE FOUNDRY AND ENGINEERING COMPANY, Ltd., Sheffield, has received a contract from the Société Métallurgique d'Imphy, France, for a bar and continuous rod mill for the production of precision alloy steel bars and rods in straight lengths and coils. Provision is made for the plant also to roll strip. The new plant will be situated adjacent to existing mills at Imphy (Nièvre). The value of the mechanical equipment is considerably over £500,000 sterling and the contract provides that some parts are to be made in France to "Brightside" designs.

British Patent Specifications

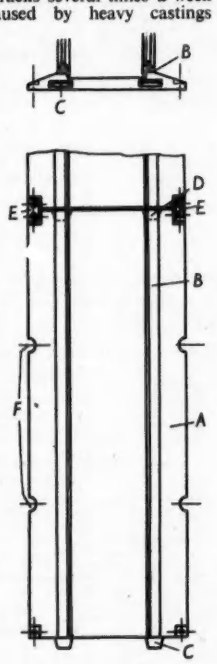
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

RAILWAY ENGINEERING

718,227. September 25, 1952.—TRACKWAY FOR RAIL VEHICLES, Gebr. Böhler and Co. Aktiengesellschaft, Elisabethstrasse 14, Vienna 1, Austria.

Wherever tracks for vehicles are subject to heavy stresses in foundries or furnace plants, it may be necessary to change the tracks several times a week because of damage caused by heavy castings slipping from the crane tongs or from a height on to the tracks. Hot castings are also liable to ignite the wooden sleepers. According to the present invention, a trackway, subjected to heavy wear in an industrial establishment, is made throughout its entire length of metal plates. The trackway *A* shown in the drawing is a cast iron plate, the breadth of which is that of the sleepers of existing track. As a substitute for the rails tread surfaces *B* are either cast integrally with or welded to the track plate. They are preferably arranged in such a way that they decline sharply inwards in order to hold the wheel flanges. One end of the plate has plugs *C* and the other end slots *D*, in order to enable the different plates to be attached with their tracks in alignment. The plates are bolted together by fish-plates *E*. In order to facilitate shifting, hooks, brackets, lugs or notches *F* may be provided. A modified design, using several metal plates, is also shown in the specification.—*November* 10, 1954.

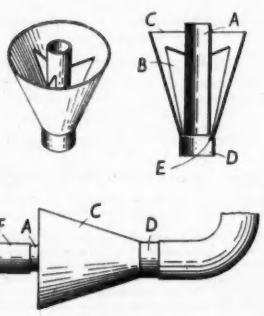


No. 718,227

INTERNAL COMBUSTION ENGINES

717,880. June 13, 1952.—DEVICE FOR FITTING TO EXHAUST SYSTEMS, Arthur Smith, Oddfellows Hall Hotel, 1, High Street, Idle, Bradford.

The invention relates to an exhaust fitting for motor vehicles to give an ejector or venturi effect when the vehicle is moving in order to increase the expulsion of the exhaust gases from the cylinders. In the construction shown in the drawing the device consists of a metal main tube *A* to which are welded three longitudinal ribs *B*, and a frustoconical outer shell in the form of a funnel *C*. The narrower rear end of the funnel has a short cylindrical extension *D*, and there is left a narrow annular clearance *E* which forms a restricted passage for air passing through the funnel. The front end of the tube fits within the end of the exhaust pipe *F* to the rear of the silencer of a motor vehicle and so that when the vehicle is in motion the rush of air through the funnel produces an ejector or venturi effect around the rear end of the tube *A*. This lowers the pressure in the tube and exhaust system and causes a suction effect on the exhaust gases. An alternative design is also shown in the specification.—*November* 3, 1954.

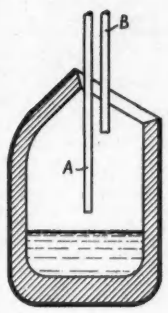


No. 717,880

METALLURGY

717,865. March 12, 1952.—BLOWING OF PIG IRON IN A CONVERTER, Oesterreichisch-Alpine Montangesellschaft, 4, Friedrichstrasse, Vienna 1, Austria.

The invention relates to a device for the blowing of pig iron in a converter in which the oxygen or air enriched with oxygen is blown against the surface of the bath. As shown in the drawing, a pipe *A* is introduced through the opening into the converter, through this pipe oxygen is blown against the bath surface. Strong reaction takes place between the oxygen and the bath, accompanied by a strong boiling movement, which would produce iron burr on the lining more particularly at points in the region of the opening of the converter. By means of an additional pipe *B*, the orifice of which lies in the upper region of the converter, near the opening, or at a suitable height above the bath, air or some other oxygen-containing gas, is blown into the converter, so that in this upper region the CO burns to CO_2, and since this reaction is exothermic the temperature is increased at the danger points. In this way a deposition of iron burr in the region of the converter opening is avoided to a large extent.—*November* 3, 1954.

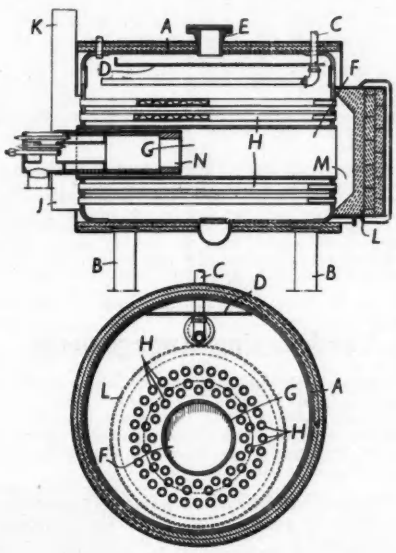


No. 717,865

STEAM GENERATORS

718,220. August 6, 1952.—HIGH-CAPACITY FIRE TUBE BOILER, The Thermal Research and Engineering Corporation, Mill Road, Conshohocken, Pennsylvania, U.S.A.

The boiler shown in the drawing comprises a shell *A* lagged and carried by supports *B*. A feed water supply pipe *C*, a foaming shield *D* and a steam outlet connection *E* are also shown. The boiler has a heat-exchanging pass *F* through which the products of combustion move. The heat-exchanging pass comprises a single fire tube *G* extending longitudinally through the shell, together with a number of smaller return fire tubes *H* substantially parallel to and surrounding the single fire tube *G*. The smaller return fire tubes together constitute a second heat-exchanging pass. The return fire tubes are connected at their opposite ends to a manifold *J* leading to the stack *K* of the boiler. A multiple layer refractory cap *L* encloses all of the fire tube ends to provide a chamber *M* which forms a part of the heat-exchanging pass. As illustrated, a burner *N* is inserted into the single fire tube *G* opposite the refractory cap *L*. Thus the heated products of combustion move rapidly over the surfaces of the heat-exchanging pass *F* to give up their heat, primarily by convection. The combustion products give up heat first to the wall of the single fire tube *G* and then to the walls of the smaller return fire tubes. Excellent results are stated to have been obtained with the aggregate cross-sectional area of the return fire tubes less than 75 per cent of that of the single fire tube.—*November* 10, 1954.

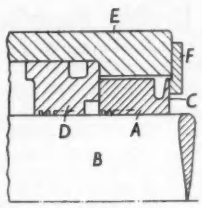


No. 718,220

POWER TRANSMISSION

717,718. April 3, 1952.—SEALS FOR ROTARY SHAFTS, Power Jets (Research and Development), Ltd., a British company, 25, Green Street, London, W.1. (*Inventor: Georges Henry Roesch.*)

The invention relates to a seal surrounding the rotating shaft of a machine containing gas at high pressure and high temperature. In the construction shown in the drawing the seal is a cylindrical ring *A* fitting on a plain shaft *B* and having the usual internal circumferential sealing grooves. The seal has, close to one end, a deep circumferential groove extending almost through its total radial thickness In this way the seal is formed with an annular springy lip *C* which can yield resiliently when the seal is compressed axially. Around the seal the internal diameter of the housing is larger than the outside diameter of the seal so as to leave it radially free, and two end faces are provided for restraining the seal against axial movement and between which the seal is resiliently compressed. when the parts of the housing are brought together. The housing is formed of a part *D* bored to fit the shaft—preferably also with sealing grooves around the shaft—a part *E* having the bore larger than the outside of the seal *A* and a clamping ring *F* fastened on the outside of part *E*. Modified designs are also shown in the specification.—*November* 3, 1954.

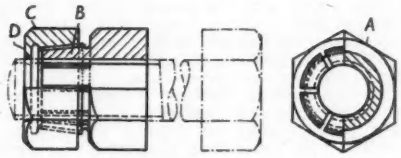


No. 717,718

MISCELLANEOUS

718,045. February 7, 1952.—LOCK NUTS, Harry Noblet, 18, Fernbrook Drive, North Harrow, Middlesex.

In the embodiment illustrated, a pair of lock nuts are shown in locking engagement on a bolt (shown in dot-and-dash lines). The main lock nut *A* has an axial extension *B* in the form of an annular sleeve, which has an internal thread forming a continuation of the thread of the lock nut. The outer periphery of the extension is frustoconical and is threaded. This extension is formed into segments by radial slots. The lock nut *C* is designed to screw on the thread on the outer surface of the extension. The outer end of this nut has a flange *D* with a central hole, through which the end of the bolt can pass freely with a small clearance. The flange protects the end of the sleeve and it may also act as a grease retainer. When the lock nut *C* is screwed on to the extension of the main nut and is firmly tightened up, it compresses the segments of the extension and forces them into binding engagement with the bolt.—*November* 10, 1954.

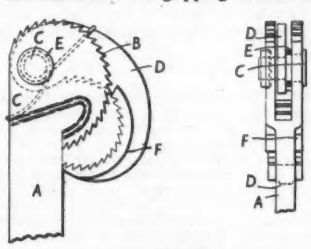


No. 718,045

TOOLS AND WORKSHOP APPLIANCES

718,528. January 15, 1952.—A WRENCH FOR PIPES AND RODS, Einar Dale, Lillesand, Norway.

The invention provides a new type of pipe-wrench which is automatic in its gripping action and automatically releases the work when turned in a reverse direction. As the drawing shows, the handle *A* is bifurcated at the top to form spaced parallel limbs with teeth *B*, which terminate at the handle. Affixing



No. 718,528

the limbs is a pivot stud *C*, held in place by a nut or collar and on this stud is freely mounted the complementary jaw *D*. It will be noted that the stud has two diameters at the centre, the jaw *D* being on the part of smaller diameter and held to one side of the slot between the two arms. On the part of the stud of larger diameter is a coil spring *E* which is under stress with its ends hooked around the respective parts *D* and *A* to keep the jaw *D* in the closed position shown. The jaw *D* has a toothed insert *F* of equal width to the jaws. By arrangement of the respective radii of curvature of the convex and concave jaws wrenches may be made in which the jaws can adapt themselves to grip objects of greatly differing diameters. A modified jaw profile is also shown in the specification.—*November* 17, 1954.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

AIR-COOLED FLAMEPROOF SINGLE-PHASE LIGHTING TRANSFORMER UNITS SUPPLIED FROM HIGH-VOLTAGE SYSTEMS

No. 2538 : 1954. Price 2s. The unit is intended mainly for the lighting of roadways in coal mines, but may also be used in other places where inflammable gas or vapour may be present in the surrounding atmosphere. Among the organisations which co-operated in the preparation of this standard were three professional institutions, together with the Association of Mining Electrical and Mechanical Engineers, British Electrical and Allied Manufacturers' Association, Ministry of Fuel and Power, National Coal Board.

HARD-DRAWN COPPER CONDUCTORS FOR OVERHEAD POWER TRANSMISSION PURPOSES

No. 125 : 1954. Price 3s. This standard is a revision of B.S. 125 : 1947, and most of the provisions of that issue have been retained. The principal alterations are the adoption of the Centigrade temperature scale, with a basic reference temperature of 20 deg. Cent., instead of the Fahrenheit scale, with a basic temperature of 60 deg. Fah., and the introduction of revised values for constant-mass temperature coefficient of resistance and coefficient of linear expansion, which are better representative values than those in the 1947 edition. In addition, the requirements of the tensile test have been altered.

STEEL COMPRESSION PIPE FITTINGS FOR ENGINEERING PURPOSES

No. 2051 : Part 3 : 1954. Price 3s. 6d. This standard covers steel compression fittings for use with pipes made of steel and other suitable materials for a variety of engineering purposes. It applies to two ranges of fittings, namely : (i) for use with pipes having fractional outside diameters, ¼in to 1¼in, inclusive ; (ii) for use with pipes designated by their nominal bores, ¼in to 1in, inclusive.

The standard does not attempt the complete dimensional standardisation of these fittings since the variety in the designs and methods of production already established by manufacturers make any such attempt impracticable. It does, however, lay down such dimensions and requirements as are essential to ensure satisfactory installation and performance.

The standard includes a number of general requirements relating to materials, design, construction and workmanship ; it specifies a hydraulic test and a test for porosity and also gives temperature and pressure ratings for these fittings.

Catalogues

THE MAGNETIC EQUIPMENT COMPANY, Ltd., Porchester, Hants.—Brochure No. 80 and Leaflet No. 46, describing the " Magco " dry and wet electro-magnetic ore separators.

BRITISH CENTRAL ELECTRICAL COMPANY, Ltd., 6–8, Rosebery Avenue, London, E.C.1.—Leaflet describing portable fluorescent hand-lamps for general purpose and barrel inspection.

ALUMINIUM RIVETING.—The Aluminium Development Association, 33, Grosvenor Street, London, W.1, has published an enlarged and revised Information Bulletin, No. 8, *The Riveting of Aluminium*, price 2s., which was first issued in 1944. The new *Bulletin* takes into account all the developments and advances in technique during recent years and opens with notes upon the chemical composition and mechanical properties of rivet materials, and the manufacture of rivets, their sizes and head shapes. Design factors as applied to riveted joints are discussed, together with the various equipments for riveting light assemblies. This is followed by similar information regarding the technique of driving of large diameter rivets. There are a number of appendices concerning standards nomenclature, mechanical testing, heat-treatment and length of rivets to form flat and cone points, and also a selected bibliography.

Launches and Trial Trips

STORAAS, oil tanker ; built by the Caledon Shipbuilding and Engineering Company, Ltd., for Iver Bugge, Norway ; length overall 556ft, length between perpendiculars 530ft, breadth moulded 72ft, depth moulded 39ft, draught loaded 29ft 10½in, deadweight 18,075 tons ; two cargo oil pump rooms, four 400 tons per hour cargo oil pumps ; one 125kW diesel-driven generator, two 120kW steam-driven generators, two oil-fired boilers ; Harland and Wolff - B. and W. two-cycle, single-acting, opposed-piston diesel engine, seven cylinders, 8000 b.h.p. at 112 r.p.m., trial speed 15 knots. Trial, November 12th.

PROTEUS, oil tanker ; built by the Netherlands Dock and Shipbuilding Company for Manuel E. Kulukindis and Associates, New York ; length overall 630ft 10in, length between perpendiculars 600ft, breadth moulded 76ft 6in, depth 43ft, draught at summer freeboard 33ft 1½in, deadweight 25,200 tons, speed 15·65 knots ; twenty-seven cargo oil compartments ; one set of double-reduction geared Parsons turbines, 9000 b.h.p. at 108 r.p.m., two Babcock and Wilcox water-tube boilers.—Launch, November 13th.

SIRIUS, oil tanker ; built by the Furness Shipbuilding Company, Ltd., for the Sociedad Transoceania Canopus S.A., Panama ; length between perpendiculars 560ft, breadth moulded 80ft, depth moulded 42ft 3in, deadweight 24,800 tons on 32ft 4in summer draught, designed trial speed 14½ knots ; twenty-seven cargo oil tanks, one main cargo pump room, three 1000 tons per hour turbine-driven centrifugal pumps, three 150 tons per hour stripping pumps ; two 385kW turbine-driven generators, one 75kW diesel-driven generator ; one set of double reduction steam turbines by Richardsons, Westgarth and Co., Ltd., 7300 s.h.p. service power at 100 propeller r.p.m., 8200 s.h.p. maximum power at 104 propeller r.p.m., steam supplied at 450 lb per square inch by two Foster Wheeler " D " boilers. Launch, November 25th.

TORVANGER, oil tanker ; built by Joseph L. Thompson and Sons, Ltd., for Westfal-Larsen and Co. A/S, Norway ; length between perpendiculars 530ft, breadth moulded 71ft 10½in, depth moulded 40ft, deadweight 18,250 tons on 29ft 6in summer draught ; eight centre and eighteen wing cargo oil tanks, two cargo oil pump rooms ; Hawthorn-Doxford oil engine, six cylinders 670mm diameter by 2320mm combined stroke, 6800 b.h.p. at 116 r.p.m., service speed 14 knots. Launch, November 26th.

HADRIANIA, oil tanker ; built by Smiths Dock Company, Ltd., for Shell Tankers, Ltd.; length overall 557ft, length between perpendiculars 530ft, breadth moulded 69ft 3in, depth moulded 39ft, deadweight 18,100 tons on 29ft 9½in draught, service speed 14½ knots ; thirty-three cargo oil tanks, one main cargo pump room, four 400 tons per hour turbine-driven cargo oil pumps, two stripping pumps, steam deck machinery ; two 550kW turbine-driven alternators, one 200kW diesel-driven alternator ; one set of two-casing double-reduction geared turbines by Hawthorn Leslie (Engineers), Ltd., steam supplied at 500 lb per square inch and 800 deg. Fah. by two Foster Wheeler " D " boilers. Trial, November.

ATLANTIC LADY, oil tanker ; built by Ateliers et Chantiers de la Seine Maritime for the Atlantic Oil Carriers ; length overall 560ft 7in, length between perpendiculars 538ft 1in, breadth moulded 73ft 8½in, depth 40ft 6in, draught 30ft 6in, deadweight 19,800 tons ; two 300kW turbine-driven generators, one 125kW diesel-driven generator ; one set of double-reduction geared Rateau-Bretagne turbines, 8900 s.h.p., steam supplied at 570 lb per square inch and 895 deg. Fah. by two Babcock and Wilcox water-tube boilers.—Trial, November.

ASTREE, cargo ship ; built by Ateliers et Chantiers de Bretagne for Société Navale Caennaise ; length between perpendiculars 295ft 3½in, breadth 46ft 11in, depth to main deck 24ft 3in, draught loaded 20ft 4in, deadweight 4000 tons, trial speed 12 knots ; one reciprocating steam engine, 2200 h.p. at 140 r.p.m., steam supplied at 230 lb per square inch by two water-tube boilers.—Trial, November.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INSTITUTION OF RADIO ENGINEERS

Thurs., Jan. 6th.—MERSEYSIDE SECTION : College of Technology, Byrom Street, Liverpool, 3, " Some Interesting Applications of Electronics to Photography," D. M. Neale, 7 p.m.——N.W. SECTION : Reynolds Hall, College of Technology, Sackville Street, Manchester, " Problems in the Design and Production of Car Radio," discussion opened by C. L. Caiger, 7 p.m.

HULL CHEMICAL AND ENGINEERING SOCIETY

Tues., Jan. 11th.—Church Institute, Hull, Presidential Address, " Some Uses of Solvents," J. B. Moller, 7.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Tues., Dec. 21st.—GLOUCESTER AND CHELTENHAM CENTRE : Cadena Cafe, High Street, Cheltenham, " Lighting of Parks and Gardens," H. A. Turner, 6.30 p.m.

Thurs., Dec. 30th.—BIRMINGHAM CENTRE : College of Technology, Suffolk Street, Birmingham, Display of New Lighting Fittings, 6 p.m.

Wed., Jan. 5th.—EDINBURGH CENTRE : Manor Club, 12, Rothesay Place, Edinburgh, 3, " Street Lighting Lantern Design," T. M. Christie, 7 p.m.——NEWCASTLE CENTRE : Liberal Club, Pilgrim Street, Newcastle, Presidential Address, E. C. Lennox, 6.15 p.m.——SWANSEA GROUP : S. Wales Electricity Board's Demonstration Theatre, The Kingsway, Swansea, Informal Meeting, Three Papers followed by a Discussion, 6.30 p.m.

INCORPORATED PLANT ENGINEERS

To-day, Dec. 17th.—BIRMINGHAM BRANCH : Imperial Hotel, Temple Street, Birmingham, MOBILE PLANT DISCUSSION GROUP : Film, " Man with a Thousand Hands," 7.30 p.m.

Tues., Jan. 4th.—LONDON BRANCH : Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, " The Writing and Presentation of a Technical Report for a Non-Technical Board of Directors," W. J. Dickie, 7 p.m.

Wed., Jan. 5th.—SOUTHAMPTON BRANCH : Polygon Hotel, Southampton, " Industrial Instrumentation," C. M. V. Benwell, 7.30 p.m.

INSTITUTE OF METALS

Tues., Jan. 4th.—OXFORD LOCAL SECTION : Cadena Cafe, Cornmarket Street, Oxford, " Titanium," P. Litherland Teed, 7 p.m.

Thurs., Jan. 6th.—BIRMINGHAM LOCAL SECTION : James Watt Memorial Institute, Great Charles Street, Birmingham, a debate on the Motion, " This house considers that, at the present stage of industrial metallurgy, empirical methods of research are more profitable than those employing the fundamental approach," proposed and seconded by D. V. Atterton and J. Crowther, opposed and seconded by A. R. E. Singer and G. Parkin, 6.30 p.m.——LONDON LOCAL SECTION : 4, Grosvenor Gardens, London, S.W.1, " Some Aspects of Twinning and Kinking in Metals," A. H. Cottrell, 6.30 p.m.

INSTITUTE OF PHYSICS

To-day, Dec. 17th.—NON-DESTRUCTIVE TESTING GROUP : 47, Belgrave Square, London, S.W.1, " X-Ray Fluorescence Analysis," E. F. Priestley, 6.30 p.m.

INSTITUTE OF REFRIGERATION

Tues., Jan. 4th.—Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, " Ground and Airborne Equipment for Cooling Aircraft Cabins," N. Anderson, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Wed., Dec. 22nd.—N.W. CENTRE : Adelphi Hotel, Liverpool, " Maintenance," H. J. Jones, 7.30 p.m.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Tues., Jan. 11th.—Institution of Electrical Engineers, Savoy Place, London, W.C.2, " The Design and Application of Tractor-Mounted Loaders," J. C. Bamford, 2.15 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Jan. 4th.—WORKS MEETING : Great George Street, Westminster, London, S.W.1, " The Reconstruction of Deptford Creek Bridge," F. M. Fuller and J. N. C. Couper, 5.30 p.m.——N.W. ASSOCIATION : Reynold's Hall, College of Technology, Manchester, " Some Applications of Reinforced Concrete in the Gas Industry," T. Andrews, 6.45 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., Jan. 3rd.—S. MIDLAND CENTRE : James Watt Memorial Institute, Great Charles Street, Birmingham, Discussion on " Sandwich Courses," opened by W. H. Taylor, 6 p.m.

Tues., Jan. 4th.—S. MIDLAND CENTRE : Town Hall, Birmingham, Faraday Lecture, " Courier to Carrier in Communications," T. B. Terroni, 6 p.m.——N. MIDLAND CENTRE : British Electricity Authority, 1, Whitehall Road, Leeds, 1, " The Co-ordination of Insulation of High-Voltage Electrical Installations," J. S. Cliff, 6.30 p.m.——MEASUREMENTS AND RADIO SECTION : Savoy Place, London, W.C.2, " Equipment of Instrumental Accuracy for Recording and Reproduction of Electrical Signals Using Cinematographic Film," H. McGregor Ross, 5.30 p.m.

Wed., Jan. 5th.—SUPPLY SECTION : Savoy Place, London, W.C.2. " The Economic Selection of Cooling Towers for Generating Stations," G. F. Kennedy and P. H. Margen, " The Application of Friction-Heat Transfer Correlations to Cooling Tower Design," P. H. Margen, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Dec. 17th.—GENERAL MEETING : 1, Birdcage Walk, Westminster, London, S.W.1, Thomas Hawksley Lecture, " Recent Studies of Metallic Friction," F. P. Bowden, 5.30 p.m.

Tues., Dec. 21st.—AUTOMOBILE DIVISION GENERAL MEETING : 1, Birdcage Walk, Westminster, London, S.W.1, " Problems Involved in the Application of Gas Turbines to Automobiles," 6.45 p.m.

Wed., Dec. 29th.—APPLIED MECHANICS' GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, Discussion, " Gaps in the Knowledge of Applied Mechanics," 6.45 p.m.

Fri., Dec. 31st.—GENERAL MEETING : 1, Birdcage Walk, Westminster, London, S.W.1, INDUSTRIAL ADMINISTRATION AND ENGINEERING PRODUCTION GROUP : " Development of the Lost-Wax Process of Precision Casting, 1949–1953," J. S. Turnbull, 5.30 p.m.

Tues., Jan. 4th.—BIRMINGHAM A.D. CENTRE : James Watt Memorial Institute, Great Charles Street, Birmingham, " Vehicle and Road Illumination," J. H. Nelson, 6.45 p.m.

Wed., Jan. 5th.—HYDRAULICS GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, Discussion, " Hydraulic Transmission : The Relative Advantages of Oil and Water," 6.45 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Tues., Jan. 4th.—MIDLAND COUNTIES BRANCH : Midland Institute, Birmingham, " Load Factor Methods of Design of Reinforced Concrete," F. G. Thomas, 6 p.m.——N. IRELAND BRANCH : College of Technology, Belfast, " Reinforced Concrete Portal Frames in Northern Ireland," J. D. Boyd, 6.45 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Dec. 17th.—INFORMAL MEETING : Pepys House, 14, Rochester Row, London, S.W.1, Question and Discussion Evening, 7 p.m.

Fri., Dec. 31st.—POPULAR FILM EVENING : Pepys House, 14, Rochester Row, London, S.W.1, " Sweet Thames Run Softly," " West Country Journey," " Spinning Wheels," 7 p.m.

Wed., Jan. 5th.—MIDLAND SECTION : James Watt Memorial Institute, Great Charles Street, Birmingham, " Power Press Safety," J. H. Price, 7 p.m.

OPERATIONAL RESEARCH SOCIETY

Mon., Dec. 20th.—ANNUAL OPEN MEETING : Royal Society, Burlington House, London, W.1, " The Accuracy and Function of Time Study," T. U. Matthew and W. Roadgers, 2.30 p.m.

REINFORCED CONCRETE ASSOCIATION

Tues., Jan. 4th.—N.W. BRANCH : College of Technology, Sackville Street, Manchester, " Some Applications of Reinforced Concrete in the Gas Industry," T. Andrews, 6.45 p.m.——MIDLAND COUNTIES BRANCH : Birmingham and Midland Institute, Paradise Street, Birmingham, " Load Factor Methods of Designing Reinforced Concrete," F. G. Thomas, 6 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., Dec. 21st.—SECTION LECTURE : 4, Hamilton Place, London, W.1, " Free Tab Control," W. J. Strang, 7 p.m.

Tues., Jan. 4th.—SECTION LECTURE : 4, Hamilton Place, London, W.1, " Recent Advances in the Knowledge of Transonic Air Flow," C. H. E. Warren, 7 p.m.